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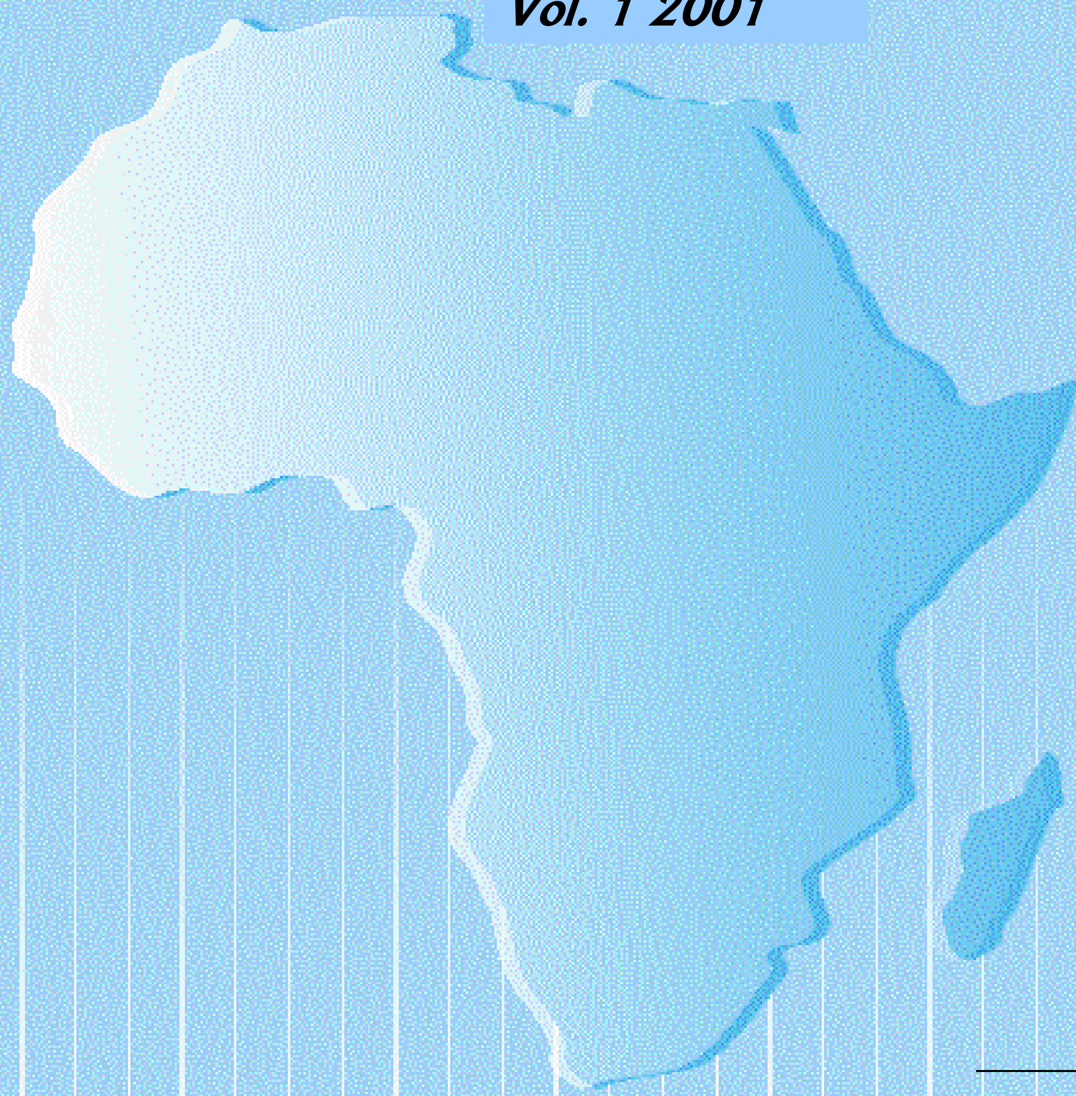

AFRICAN JOURNAL OF EDUCATIONAL STUDIES IN MATHEMATICS AND SCIENCES

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EDITORIAL

The African Journal of Educational Studies in Mathematics and Sciences (AJESMS) is an International and Interdisciplinary publication for works of high academic quality. The Journal provides a forum for researchers and organizations whose professional calling falls within the fields of Educational Studies in Mathematics and the Sciences in Africa and the rest of the World.

The articles in this first issue of AJESMS have been carefully and succinctly selected by experts on the Editorial Board to reflect the interdisciplinary nature of the Journal.

In all, ten well-researched articles are published in this first volume. These include: Determination of Electron Temperature and Election Density in Double Probe Method; Development of Remedial Method for Teaching Electric Circuits in Secondary Schools; Application of Quality Assurance in an Educational Chemistry Laboratory; The Effect of Alternative Assessment on the Attitudes and Achievement in Mathematics of Female Pre-Service Teachers in Ghana; A Comparative Study of Rasch and Zillers Models of Item Analysis; The Computer in the Mathematics Classroom; The tool, The tutor and The Tutee; An Investigation into Factors that Influence Teachers coverage in Primary Mathematics; The Appraisal of Mathematics Teachers in Ghana and Graphing Calculators: A way forward.

It is the hope of the Editorial Board that professionals and researchers in Educational Studies in Mathematics and the Sciences would find the journal to be highly educative.

PROF. M. F. ALONGE

Contents Volume 1, 2001

Determination of Electron Temperature and Electron Density in Laboratory Plasmas Using the Double Probe Method

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Abstract

The electron temperatures and electron densities of air and argon have been measured at various pds (pressure times distance). The electron temperatures have been computed using the Johnson-Malter double-probe method. The electron densities have been computed using the total positive ion current and the cross-sectional area of the probes. It is seen that the electron temperature increases from $5.8 \times 10^2\ ^oK$ to $7.83 \times 10^4\ ^oK$ as the pd is reduced from 130mm Hg × mm to 60 mm Hg × mm for argon. The electron densities increases from $2.8 \times 10^{11}/cm^3$ to $3.2 \times 10^{11}/cm^3$ for the same variation of pds. For air the electron temperature increases from $3.6 \times 10^4\ ^oK$ to $7.80 \times 10^4\ ^oK$ as the pd is reduced from 130 mm Hg × mm to 60 mm Hg × mm. The electron density increases from $4.4 \times 10^{11}/cm^3$ to $6.3 \times 10^{11}/cm^3$ for the same variation of pd.

Introduction

The strongest reason for the study of laboratory plasmas is undoubtedly the prospect of producing a virtually inexhaustible supply of energy by means of a controlled thermonuclear reactor (Strait et al., 1995). The most feasible way of achieving such a reaction appears to be by means of high temperature plasmas (Krall et al., 1995). In this regard all third would countries cannot afford to be seen lagging behind in that technology. A study of laboratory plasmas must be actively pursued.

Knowledge of electron temperature is of importance in the determination of such quantities as the am bipolar diffusion coefficients. In the present paper we report the measurement of electron temperature and density by

using the double probe method (Johnson & Malter 1950). This method has since been successfully applied to study the discharges between both conducting and non-conducting electrodes (Bhiday et al, 1972). The double probe method has the advantage that is exerts a negligible influence on the discharge and yields fairly accurate temperature data in all types of discharge including decaying plasma. Both the discharge tube and the copper electrodes were fabricated locally.

Materials and Methods

Theory

A plasma is a quasi-neutral gas of charged and neutral particles exhibiting collective behaviour. To full-fill the basic physics involved in controlled thermonuclear reactors a gas must satisfy certain conditions before it can be called plasma. These are:

i. Ne $\approx Ni$

ii. $\lambda_D << L$

iii. $\frac{4}{3}\pi\lambda^3{}_D N >> L$

iv. $\frac{2\pi}{w_p} < \frac{1}{v_c}$

v. L = length of interest e.g. dimension of plasma where Ni = ion number density

Ne = electron number density

λ_D = Debye Length

U_c = Collision frequency

ω_p = Plasma frequency

1. This criterion specifies overall charge neutrality.

2. The Debye length or shielding distance is defined by the equation.

$$\lambda_D = \left(\frac{\varepsilon_0 k T_e}{N_e e^2}\right)^{\frac{1}{2}}$$

Where ε_0 is the permitivity of free space k is Boltzmann=s constant, T_e is the electronic temperature and e is the electronic charge. This criterion states that λ_D is a measure of the minimum size of a system such that the collective effects are dominant as compared to single particle effects.

3. In order to obtain the equation for λ_D one assumes a smooth change in electric field in the region of the particle under consideration. This necessarily involves the assumption of a large number of particles in the neighbourhood. The third criterion ensures that this condition is satisfied.

4. The plasma frequency ω_p is defined by the equation

$$w_p = \left(\frac{N_e e}{m_e \varepsilon_0} \right)^{\frac{1}{2}} \tag{2}$$

Where m_e is the electron mass. Collective oscillations of plasma are related to ω_p. In order that these oscillations may develop, collisional dumping must be small. This will transmission of electromagnetic waves through plasma.

On the basis of these criteria, plasma may be regarded as an electrically neutral fluid containing neutral and charged and capable of maintaining a broad spectrum of oscillations.

The Conception of Electron

A gas in thermal equilibrium has particles of all velocities and the most probable distribution of these velocities in the Maxwell Ian distribution. The one-dimensional Maxwell Ian distribution given by Chan (1984) is

$$f(u) = A \exp\left(-\frac{\frac{1}{2}mu^2}{kT} \right). \tag{3}$$

Where f is the number of particles per cm^3 with velocity between u and $u + du$, $\frac{1}{2}mu^2$ is the kinetic energy and m is the mass of the particle. The density N or number of particles per cm^3 is given by

$$N = \int_{-\infty}^{+\infty} f(u) du \tag{4}$$

The constant A is related to the density N by

$$A = N\left(\frac{m}{2\pi kT} \right)^{\frac{1}{2}} \tag{5}$$

The width of the distribution is characterized by the constant T, which we call temperature.

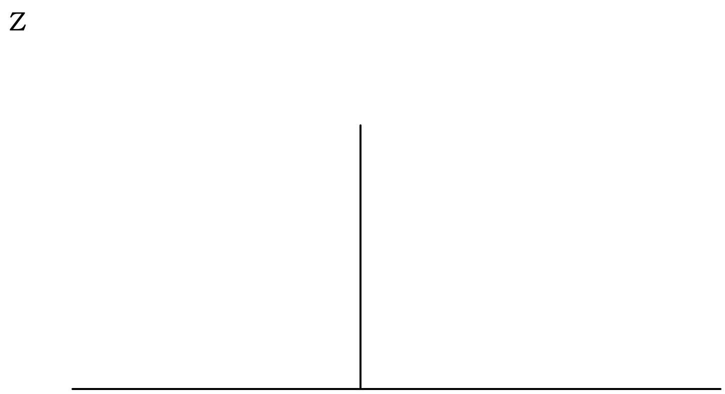

Fig. 1 Maxwellian velocity distribution

To see the exact meaning of T we can compute the average kinetic energy of particles in this distribution.

$$E_{av} = \frac{\int_{-\infty}^{\infty} \frac{1}{2} m u^2 f(u) du}{\int_{-\infty}^{+\infty} f(u) du} \qquad (6)$$

Defining $$v_{th} = \left(2kT/m\right)^{\frac{1}{2}} \qquad (7)$$

And y = u/v_{th}

We can write equation (3) as

$$f(u) = A \exp\left(\frac{-u^2}{v^2{}_{th}}\right) \qquad (8)$$

and equation (6) as

$$E_{av} \frac{1/2 m A v_{th}{}^3 \int_{-\infty}^{+\infty} \left[\exp\left(-y^2\right)\right] y^2 dy}{A v_{th} \int_{-\infty}^{+\infty} \exp\left(-y^2\right) dy} \qquad (9$$

The integral in the numerator is integrable by parts, canceling out the integrals we have

$$E_{av} = \frac{1/2 m A v^3{}_{th} \, 1/2}{A v_{th}} = \frac{m v^3{}_{th}}{4} = \frac{kT}{2} \qquad (10)$$

Thus the average kinetic energy is ½ KT. In three dimensions Maxwell∍s distribution becomes

$$f(u,v,w,) = A_3 \exp.\left[\frac{-1\!\!\diagup\!\!2m\left(u^2+v^2+w^2\right)}{kT}\right] \qquad (11)$$

Where $A_3 = N\left(\frac{m}{2\pi kT}\right)^{\frac{3}{2}}$

The average kinetic energy is then given by

$$E_{av} = \frac{3kT}{2} \qquad (12)$$

The general result is that E_{av} equal $= \frac{kT}{2}$ per degree of freedom. Since T and E_{av} are so closely related, it is customary in plasma physics to give temperatures in units' energy. The conversion factor is

There is always the popular misconception that high temperatures necessarily mean a lot of heat. People are usually amazed to learn that the electron temperature inside a fluorescent light bulb is about 20000 K, but it does not feel that hot!

The heat capacity must also be taken into account. The density of electrons inside a fluorescent tube is much less than that of a gas at atmospheric pressure and the total amount of heat transferred to the wall by electrons striking it at their thermal velocities is not that great. Many laboratory plasmas have temperatures of the order of 1 x 10^6 K (100 eV), but at densities of 10^{11} – 10^{12} per cm^3 the heating of the walls is not a serious consideration.

Experimental set-up

The attempt to determine characteristic properties of plasma discharge by electric probes was one of the first ways in which Physicists tried study such discharges. The earliest work simply involved measuring the potential by an isolated probe upon its insertion into the plasma (Johnson & Malter, 1950).

The main disadvantage of the single probe is that a large electron current can be drawn from the plasma and also the probe has to be connected to some external potential thereby seriously changing the properties being measured. This could be overcome partially by using a double probe system.

The double-probe consists of a pair of ordinary Langmuir symmetric probes inserted into the plasma as close together as possible consistent with their

sheaths not overlapping. The overall assembly is allowed to float electrically but a potential difference is placed between the two probes. Such an assembly has the advantage of making the measurements independent of the actual potential of the ambient plasma but still earn probe individually disturbs the plasma in its region.

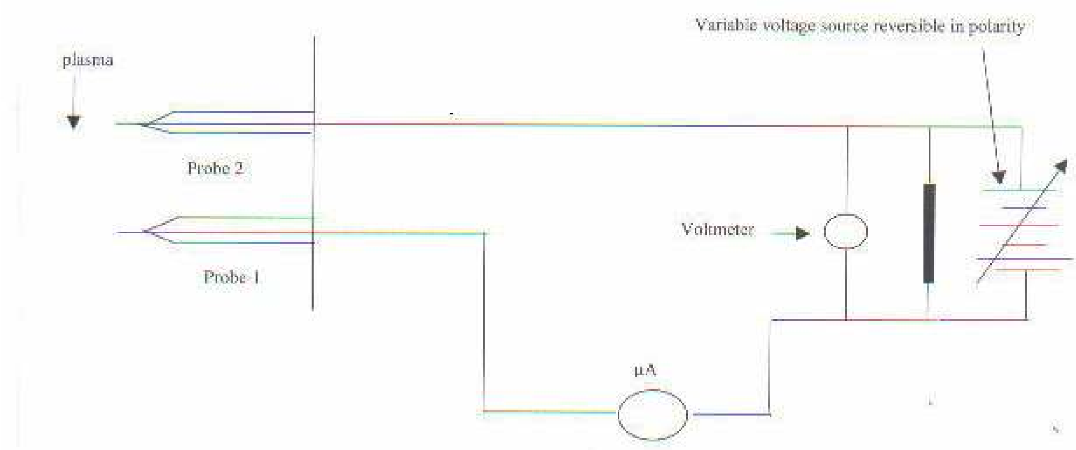

Fig.2 Double Probe Circuit

The probe circuit is shown in Fig. 2. Since the two probes are floating, they tend to be negative with respect to the plasma so it is assumed they collect the full positive ion current. It the potential applied between them is V_d then the space charge potential effect gives the potential levels of the two probes. Since no currents are drawn from the plasma, then the total electron currents must be equal to the ion currents (Gholap, 1972).

$$i_{e1} + i_{e2} = i_{i1} + i_{i2} = 2\, i_s \tag{13}$$

Where i_{e1} and i_{e2} are electron currents on probes 1 and 2 i_s the saturation current, i_{i1} and i_{i2} are ion currents on probes 1 and 2, respectively.

The current that passes through the probe circuit must be equal to half of the difference of the electron currents.

$$i_{e2} - i_{e1} = 2 i_d \tag{14}$$

Where, i_d is the difference in electron current from the two probes called the circuit current. The circuit current i_d is related to the differential voltage V_d by

$$i_d = i_{sa} \exp\left(\frac{-V_d}{kT_e}\right)$$

(15)

Where

i_{sa} = Saturation current of a particle
V_d = Differential voltage
T_e = Electron temperature.

In brief the electron temperature is determined from the way in which i_d varies with V_d.

If the potential difference between the probe is increased, then the relatively positive probe collects more electrons until at a certain potential, it reaches saturation.

In this work, the probe system was made from two copper wires having uniform diameter of 0.68 mm. These wires were cut from the same piece of copper wire to ensure similarity in all respects. In order to avoid sharp points in the discharge, the tips of the wires were rounded off. The major portion of the probes was shielded by specially designed glass capillary tubes and only a small length (about 0.5 mm) of each probe was exposed to the discharge on the axis of the tube. The dimensions of the probes were such that the length of the probe was smaller than the mean free path of electrons and greater than the Derby length, which is a measure of the thickness of the sheath around the robe. Under such condition the probe will cause least disturbances of the plasma and the results could be interpreted correctly.

The current to the probe was measured with the help of a sensitive scalamp galvanometer with suitable shunts. The voltage applied to the probes was from a variable 24 V dc supply. The probe potential could be varied in steps of 1,0 V and could be reversed in polarity. Measurements of i_d and $\boldsymbol{V}_d$ were done for both air and argon at different pds.

Results

The Electron Temperature and Electron Density

A typical i –V characteristic of the double probe is shown in Figs 3. The characteristics have 3 distinct regions like the universal probe characteristic. There are two regions of saturation and a straight part, which joins these, and form the third region.

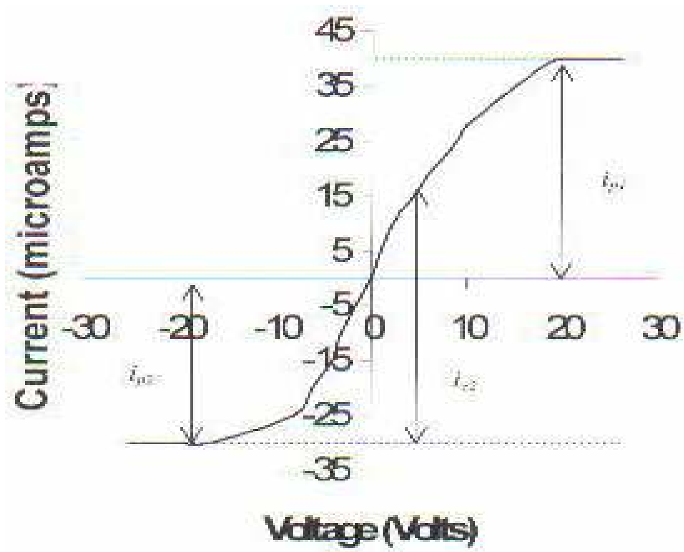

Fig. 3 *i–V* characteristic of the double probe

These characteristics are reasonably symmetrical about both axes and the values of the ion currents i_{i1} and i_{i2} collected by both probes are nearly equal to each other. The values of the ion current collected by the probes 1 and 2 (i_{i1} and i_{i2}) and the electron current i_{e2} are calculated from their V characteristics of the double probe shown in the in Fig 3. The semi-log plots of $\left[\sum \frac{i_p}{i_{e^2}} - 1\right]$ against V_d are shown in Fig 4, where i_p is the total positive ion current of the system, which is simply the sum of the positive ion currents to both probes.

From the slope of the these straight-line curves the electron temperature was calculated using the relation,

$$T_e = \frac{116000}{\Phi}$$

Where Φ is the slope of the straight-line curve.

The variation of electron temperature with pd for both air and argon is shown in Tables 1 and 2 respectively.

Table 1. VARIANCE OF T_e AND N_e WITH PD (PRESSURE X DISTANCE) FOR AIR

Pd (mm Hg X mm)	T_e (X 10^4 ^{0}K)	N_e (X 10^{11}/cm ^{3})
130	3.60	4.40
100	5.20	6.10
60	7.80	6.30

Table 2 VARIATION OF T_e AND N_e WITH PD (PRESSURE X DISTANCE) FOR ARGON

Pd (mm Hg X mm)	T_e (X 10^4 ^{0}K)	N_e (X 10^{11}/cm ^{3})
130	5.80	2.80
100	6.40	3.10
60	7.73	3.20

The electron densities were calculated knowing the area of the probe and the value of the total positive ion current.

$$N_e = \frac{J}{A}\left[\frac{2\pi m}{kT_e}\right]^{\frac{1}{2}}$$

Where $J = \sum \frac{i_i}{A}$ and A is the area of the probe. In gaseous plasmas concentration of positive ions is almost equal to that of electrons, thus $N_e \approx N_i$. The variation of electron density with pd for both air and argon is also shown in tables 1 and 2 respectively.

Discussion

The variation of electron temperature with pd agrees qualitatively with the theoretical variation as given by the equation (Meek and Craggs, 1953)

$$(pd)^2 = \frac{\pi^2 kT}{e\left(E/p\right)\left(a/p\right)}$$

Where E is the breakdown gradient, a is Townsend first ionization and all the other symbols have their usual meanings.

The variation of electron density as seen in Table 1 and 2 is consistent with theory as given by the equation

$$N_e = A\exp\left({}^{eV}\!/_{kT_e} \right)$$

Where A is a constant, V is the breakdown potential and all the other symbols are as defined before. The higher values of N_e for argon may be attributed to its high first ionization coefficient.

The concept of electron temperature is valid only if the electrons have a Maxwell Ian velocity distribution. It could be safely concluded that this was so in this case as is evident from the straight-line curve of fig 4. Thus the conditions under which the double probe method is valid were obtained in these measurements.

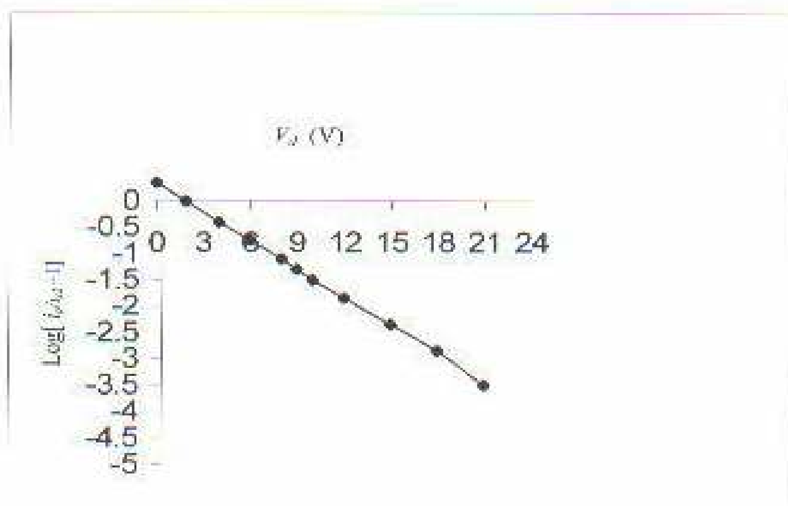

Fig. 4   A plot of log [$\Sigma \frac{i_p}{i_{e2}} - 1$] against V_d

Conclusion

A double probe method has been used to determine plasma temperatures and densities. The results compare very well given using other methods and are more reliable than for the single pulse method. This experimental set-up can easily be adapted for use in any Physics laboratory for educational purposes.

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Applications of Quality Assurance in an Educational Chemistry Laboratory

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Abstract

It is a well-known fact that, the over all student performance in practical work is a function of a closely interwoven ternary system that includes the teacher, the laboratory technician and the student. The contribution of these people towards the success of a students starts from experimental design and reagent preparation stages. The implementation of a quality assurance system in a Chemistry laboratory reduces shortcomings associated with student failure, which includes unpreparedness, mismanagement of time, lack of practical work techniques, improper data processing and presentation. This can be instituted, in part, by the application of cheap and reliable reference materials made by the teachers. A collaborative proficiency-testing group involving a number of Chemistry teachers and peers can be set to select suitable candidates for reference materials. A quality assurance system installs teacher confidence that the Chemistry laboratory is performing effectively in training students.

KEYWORDS: Quality, Quality assurance, Quality Control, Reference Materials, Laboratory, Chemistry practical, Collaborative Testing.

Introduction

Over the years quality methodologies have been largely developed and applied to industrial processes that involve inspection and testing of processes and machinery to ensure strict adherence to laid down protocols that meet the customers' specifications. The application of quality assurance in industry has been and still is a success due to the ever-increasing competition in the production of high quality goods that attract a larger market share whilst being economically sustained (Montgomery, 1996 and Lal, 1993). During the inspection and testing procedures, analytical methods equivalent or similar to the ones employed in educational practical work are sued to check for product or process compliance to certain standards or regulations. To this end, if constituted and applied properly, quality assurance will obviously improve the pass rate of chemistry practical in educational environments.

Practical work is as equally important as theoretical work and as such students will have the privilege of complimenting the two and grasping a clearer and defined understanding of certain chemical principles.

The applicability of quality assurance and quality control on practical work in high schools and some higher institutions of leaning will undoubtedly enhance laboratory efficiency and simultaneously increase the low practical component pass rate being currently envisaged. To develop quality assurance personnel for industry and the management of educational institutes it would be therefore important to introduce and impact the knowledge during their high school, University or any other post high school studies.

The quality assurance procedure being presented can be summarised into three main sections of primary importance viz.:

(i) Start right: Preparations that are done prior to the execution of an experimental design.

(ii) Keep right: Quality control and quality assurance techniques carried out to ensure that the experimental procedures conform to the desired specifications.

(iii) Finish right: : Involves data manipulation and presentations that should answer the objectives of the experiments.

Start Right

The principal objectives of restricting to a prescribed quality assurance procedure is to achieve a status where the student cannot get erroneous misleading information but obtain accurate data, where dependable information can be extracted and used constructively. In carrying out practical work, when the above mentioned procedures are followed cautiously and religiously, there is virtually no way a student or a technician can go wrong. It should be ensured that the chemicals bought are of the expected quality and will not in any way have some detrimental effects on the outcome of the experiments in which they are going to be used.

In starting right, before carrying out any mixing of reagents, quite often the students are supplied with a standard method well before the execution of the practical. It is of utmost importance that students go through the practical manual or schedule such that they can simplify the practical methodology so as to come up with their own itemised stages and easy to follow experimental designs. Obviously the treatment of an examination and routine practical work require similar attention but the urgency of quality control slightly differs. On routine practical course work, practical schedules are normally given days, if not weeks before carrying out the practical work, giving the student ample time to go through the document and make necessary preparations before hand. For examination practical, the start right preparations should have been nurtured throughout the

course such that with a well-groomed student the requirements for starting right can be done within a short space of time without any impediments.

In coursework assessment practical, a significant amount of time is saved from trying to read and understand what the practical work entails and simultaneously trying to figure out the best way of assembling the apparatus. In most cases unprepared students carry out their practical haphazardly resulting in large quantities of chemicals being wasted. For example in acid base titration's, if a large volume of a highly concentrated titrant is used instead of using a small aliquot, large volumes of the titre chemicals will be required to reach the end point resulting in a latent loss of revenue. Additionally an unprepared student will have insufficient time at his disposal to think on how to apply certain prescribed methods and techniques during the course of the practical which of course is expected from them. The overall result is the high probability of producing wrong results, because, sometimes they will not use stated and approved procedures required in the handling and cleaning of equipment and glassware they will be using.

Frequently, the chemical reagents used are normally prepared by the school technician or the teacher, but it is also very important to have students carry out the entire process on their own. This will expose them to the nitty gritties of preparative work, which are very essential in the experimental design. In that way, they will become mature, self sufficient and ready for the practical examination.

In summary pre-laboratory techniques done in the start right procedure help the student abundantly in the following situations.

(i) Evaluation and comparison of practical work ethics and processes

(ii) Evaluation and the use of other choices of chemicals and equipment that can be employed if the desired ones are not available without altering the course of the reactions and compromising the quality of results.

(iii) Special precautions that must be adhered to in order to preserve chemicals and to protect other students from accidental spills and vapours emanating from reaction vessels. The American Chemical Society (1979) resolved that there is always a safer way of conducting any experiment.

(iv) The use of calibrated equipment. Most laboratories in schools do not have a systemised procedure for instrument calibration and, if it is available sometimes a way of identifying a calibrated equipment will be non existent. It is imperative that such information be made available or displayed near the instrument to acquaint the would be users.

(v) If all the movable and handy equipment is supplied then it would be appropriate that they be placed within the reach of the students to avoid unnecessary movement, which might prove costly in terms of

time and, the noise created can sometimes distract others from concentrating on their work.

(vi) Bearing in mind that results of a particular analysis have a strong correlation with sampling, a careful sampling protocol must be followed to minimise bias.

Keep Right

Standard operating procedures and good laboratory practices are the most vital tools in keeping up with right stage. The students should always be on guard to avoid short cuts as they sometimes results in excusable offences such as explosions occurring as a direct consequence of improper instrument use and the mixing of incorrect reagents. Specific procedures of handling chemicals should be well advocated for by the responsible authorities and this should be clearly documented to make sure that all students are properly informed in this regard. Safety measures and the practical work protocol must be strictly followed to ensure a desirable success of the experiment..

The students, by now must have already familiarised themselves with the required techniques before the onset of the experiment. If it is a titrimetric experiment, then the following should be considered.

(i) Greasing the stopcock

(ii) Removal of air bubbles that may have developed inside the burette tip.

(iii) Titre readings should be made to the nearest 0.02ml for a 50ml burette.

(iii) A white background should normally be incorporated at the base of the reaction vessel to allow accurate end point detection.

It is important that, the standard reagents prepared be tested against a Reference material (Taylor, 1981) made by the laboratory personnel. A reference material is a substance with one or more properties, which are sufficiently established to be used for the calibration of an apparatus or, the assessment of a measurement method or for assigning values to other substances (ISO Guide 30, 1981). Most high schools have a myopic belief that internal/external Reference materials are only for industrial use or they are only employed, if and only if, there is a bias towards certification by accreditation bodies such as the International Organisation for Standardisation. The Reference materials can be used to enhance their credibility in the way in which they conduct and assess practical work. Production of these Reference materials can be done by encouraging a group of schools to develop a program that involve teachers, students and technicians in mapping out the design of experiments. An organising committee can be constituted with the mandate of designing a procedure of validating reference materials. The students, in the form of a club society or as class will definitely enrich their practical skills if their participation of

satisfactory and well supervised. Once the use of Reference materials is in place, the participating laboratories will have the assurance that their reagents, prepared after being standardised or tested against them, can be used anytime during their determined shelf life without any problems. In this way anomalies made in the preparation stage can quickly be identified and corrected before proceeding with the experiment. This procedure becomes critical in circumstances where the reagents are being immediately used in an examination where time is a limiting factor. Occasionally there will be insufficient time and resources to repeat an experimental procedure and therefore the testing stage ensures a consistent supply of quality reagents to the students. It is essential to have technicians and teachers who are adequately informed about the activities behind the use of Reference materials. This will indeed help them in identifying the use of Reference materials among schools or any other organisation, inter-laboratory proficiency testing is encouraged (Pszonicki, 1985). The organising committee should find cheap, stable and rugged materials that have the potential and the capacity of being used as Reference materials. On the other hand inter-laboratory comparisons provide a framework for independent assessment or evident that instil confidence in the teacher and the school officials that their laboratory is quite effective in producing quality results. The results analysed and interpreted by the organising committee (Horwitz, 1982). Quality is inversely proportional to results variability or is defined as the reduction in the spread of results (Montgomery, 1996). It should be noted that experimental results vary from one laboratory to another and hence ways of reducing the spread of results amongst participating laboratories should be applied and reviewed periodically.

It now seems, as through, quality assurance is an insurmountable task requiring a lot of resources. There is a growing realisation that the cost of implementing and maintaining a quality system is cheaper than the expenses incurred in dealing with the problems associated with quality deficiencies such as repeating the whole practical procedure and the loss of "excess" unused chemicals resulting from unpreparedness. In Germany losses due to poor laboratory performance by the analytical laboratories estimated, in 1984, to be in the region of I billion DM (Cali, 1975 and Crieprink, 1984). In essence an effective Quality assurance system should be able to result in a drastic decrease of expenses associated with failure by minimising the chances of repeating an experiment.

Finish Right

When all hands on practical work has been accomplished, and all the necessary information has been recorded, report writing follows. The best presentation of data must be sought for and this should be in line with the objectives made in the start right stage. All the stoichiometric calculations must be carried out after writing a balanced chemical equation for the pertinent reaction(s). Dilution factors are often mistakenly excluded or omitted from the calculations because students always have the tendency of wanting to get an end result without meticulously considering the effects of

each stage encountered. Proper rounding off of figures to a correct number of significant figures, corresponding to instrumental accuracy, should be taken care of. A majority of students repeatedly turn a blind eye on this essential feature thereby ending up propagating rounding off errors to the final result where misleading information is presented. (Cambridge University, 1999). All the results should be discussed accordingly and in some cases with an aid of statistical principles (Montgomery, 1991).

Conclusion

It is imperative that during the running of practical, the students should be advised to plan accordingly so as to start doing the experiment right and always religiously keeping right with the practical protocol and thus, there is absolutely no chances of them getting astray. The students will be assured of getting dependable results " Right first time" thereby saying time and resources, which might be called for in the event that they make mistakes. Collaborative proficiency testing between school laboratories can be instituted to allow for the development of cheap reference materials which can be used to instil confidence in the day to day running of a laboratory. The teacher or the supervisor plays a pivotal role in the success of their student and as such they should be sufficiently informed about quality practical work that includes the use of Reference materials in the preparation of some reagents. Quality is considered to be free. (Aurora, 1996). The cost of dealing with problems associated with teacher and student failure in doing practical work in most cases normally outweighs the capital invested in implementing and maintaining a quality assurance system.

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The Effect of Alternative Assessment on the Attitudes and Achievement in Mathematics of Female Pre-Service Teachers in Ghana

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Abstract

This paper examines the effect of exposing one of two groups of pre-service female teachers to alternate forms of assessment. Both groups were first year students in a teacher training college and received 8 weeks of normal instruction in mathematics content and traditional assessment by the same teacher. The students were interviewed on their attitudes towards mathematics before and after instruction. In addition, the students took two pretests and corresponding posttests. The external achievement tests were similar to the 1997 Mathematics Paper of the Senior Secondary School Certificate Examination (SSSCE) and the internal achievement tests were based on the content of instruction. The results of the study showed significant improvement in both the internal and external achievement of the experimental group, but only significant improvement in the internal achievement of the control group. Also, the experimental group achieved higher gains on both achievement tests than the control group. Students in the experimental group exhibited greater positive attitudinal changes and expressed the benefits they derived from the alternative assessment activities in their journals and portfolios. Suggestions for intervention programmes to improve female pre-service teachers' attitudes, achievement and participation in mathematics are discussed.

Introduction

Pre-service teachers are admitted directly into Teacher Training Colleges in Ghana based on their performance in the Senior Secondary School Certificate Examination (SSSCE). All pre-service teachers take mathematics content for the first two years of the three-year teacher education programme. Studies on achievement of secondary school students in

Ghana show a low achievement in mathematics and females' achievement is lower than that of males (Eshun, in press). The lower achievement of females in mathematics is reported in studies in other countries (Carpenter, Lindquist, Matthews and Silver, 1983; APU, 1985; Maqsud and Khalique, 1991; Randhawa, 1991). The achievement of pre-service teachers in mathematics is far lower than that of most secondary school students in Ghana. In 1998, about half of the pre-service teachers scored less than 17 per cent in basic mathematics which were the contents of their end of year-one examination, designated Part I Examination (University of Cape Coast - Institute of Education, 1998).

Ghana embarked on a comprehensive education reform in 1987 and teachers of high calibre and professional competence are needed in adequate numbers (Ghana Ministry of Education, 1993) to implement it and achieve the expected goals of functional literacy and numeracy for all pupils. But the results of Criterion Reference Tests (CRT) conducted between 1992 and 1995 indicate that only 1.8 per cent of primary grade 6 pupils have mastered the items in mathematics and the mean performance is less than 30 per cent (Ghana Ministry of Education, 1995).

All pre-service teachers in Ghana are trained to teach in primary grades 1 through 6. The very poor grades in mathematics of pre-service teachers in the SSSCE and their continued poor performance in the 3-Year Post Secondary Teacher Training College Examination in Basic Mathematics negatively impact on their teaching of mathematics in the primary schools and are a contributing factor in pupils' dismal performance in the CRT. Thus it is crucial that pre-service teachers' performance in mathematics be improved.

As part of the Educational Reform of 1987 continuous assessment of students (throughout the school year) and external examination are used to assess students' work for final certification (Ghana Ministry of Education, 1987) at all levels of education. Host and Bloomfield (1975) recommended the continuous assessment model as a better system of assessment than just a 2- or 3-hour examination. Continuous assessment is therefore expected to improve, and make more reliable, teachers' assessment of students' work. But in Ghana the emphasis on traditional forms of assessment such as quizzes and tests in continuous assessment make it less effective in improving students' learning and thereby their performance.

Alternative assessment is a generic term referring to the new forms of assessment (Winzer, 1992) other than traditional forms of assessment. The main goal of alternative assessment is to "gather evidence about how students are approaching, processing, and completing "real-life" tasks in a particular domain" (Garcia and Pearson, 1994). Alternative assessment may include interview with students, journal writing, students' development of portfolios of their work and writing of reflections on it. Also, students are encouraged to engage in small-group cooperative learning and be assessed individually and jointly. Thus in the alternative assessment process, a

student gets the opportunity to be responsible for selecting products of his/her work on which to be assessed and to reflect on his/her learning experience, pointing out what he/she understands and factors that contribute to his/her lack of understanding (Huerta-Marcias, 1995).

A major advantage of alternative assessment as a tool for assessing students is that it empowers them to become partners and decision makers in their learning (Smolen et al., 1995). Lee (1997) found that the real value of alternative assessment is an information source for teachers and a learning tool for the students. Viaskamp (1995) found that alternative assessment processes engage students to become active in learning through reflection and judgment of their own learning.

It is important to provide pre-service teachers with a form of assessment that enables them to identify their strengths and weaknesses in learning mathematics in order to improve their performance. In the process they will acquire a system of assessment that they in turn can use with their pupils in the primary school. Alternative assessment is very much new in Ghana. This study in alternative assessment and especially with female pre-service teachers is therefore intended to:

i. Examine the effect of alternative assessment on female pre-service teachers' performance in mathematics.
ii. Describe the effect of alternative assessment on female pre-service teachers' attitudes towards mathematics.
iii. Examine female pre-service teachers' perceptions about alternative assessment as a tool for demonstrating their progress in mathematics

Method

The population for the study was the 1998/99 first year pre-service female teachers in the Central Region of Ghana. The sample consisted of two intact classes of students in OLA Training College in Cape Coast. Tests similar to the SSSCE Mathematics Paper 1 for 1997 was constructed by the researchers and referred to as external achievement tests. Also, tests based on the mathematics content to be covered during the study was constructed and referred to as internal achievement tests. A pretest of the external achievement test was administered to both classes of students. The class with the higher mean score was designated as the control group and the one with the lower mean score as the experimental group. The two groups were also given a pretest of the internal achievement test. Both groups were then given instruction for eight weeks based on the Post Secondary Teacher Training College Mathematics Syllabus for Year One by one of the researchers and given traditional assessment during the period of the study. In addition the experimental group was given a treatment consisting of the various forms of alternative assessment. At the end of the study, the groups were given posttests on the external and internal achievement tests and their performances analysed and compared.

Using the pretest results, three ability strata were defined. These were the top 25% as the high ability group, the middle 50% as the average ability group and the bottom 25% as the low ability group. A random selection of three, four and three students from the three ability groups respectively was made for each of the experimental and control groups. These students were interviewed before and after the study to examine the changes in their attitudes towards mathematics and in their knowledge about mathematics concepts on the internal pretest items. Guidelines were given at the beginning of the study to the experimental group to enable them work successfully in small-group cooperative learning settings, write suitable reflections, keep journals and develop portfolios.

Results

Pretests and Posttests

Table 1 shows the mean scores on the two pretests and two posttests given to the experimental and the control groups. The total scores for the internal and external achievement tests were 15 and 20 respectively. The t-test values for the difference between the mean scores for the two groups on the internal and external pretests were 0.2 and 1.6 respectively, which are not significant. Thus there was no significant difference between the mathematics achievements of the two groups on both pretests. The groups were therefore equivalent at the beginning of the study. The t-test values for the difference between the mean scores on the pretest and posttest for the internal and external achievement tests were 6.9 and 3.4 respectively for the experimental group and 4.7 and 1.3 respectively for the control group. Thus there was significant improvement in the achievement of the experimental group on both the internal and external tests. While there was significant improvement in the achievement of the control group on the internal tests, there was no significant improvement in their achievement on the external tests.

Table 1. Mean Scores On Pretests And Posttests Achievement Measures

Group	Pretest	Standard Deviation	Post-test	Standard Deviation
Internal Achievement				
Control Group	4.4	2.7	7.4	3.1
Experimental Group	4.3	8.6	8.6	2.6
External Achievement				
Control Group*	4.0	2.9	4.9	3.4
Experimental Group**	3.0	2.6	5.0	2.5

* number = 41 ** number = 38

Table 2 Mean Scores of Students on Internal Pretest and Posttest by Type of Group And Ability Level

	Group		t-value
	Experimental	Control	
Low Ability			
Pretest	1.6	1.4	
Posttest	7.3	4.6	
Gain	5.7	3.2	2.84*
Average Ability			
Pretest	3.6	4.3	
Posttest	8.2	8.0	
Gain	4.6	3.7	2.03
High Ability			
Pretest	7.6	8.0	
Posttest	10.5	10.0	
Gain	2.9	2.0	1.87

*$p < 0.05$

Table 2 shows the mean scores for students at three ability levels, low, average and high for each of the experimental and control groups on the internal pretest and posttest. The results show that there was significant difference between the mean gain scores of the low ability groups but no significant difference between the average and high ability groups. However, the low ability students in the experimental group achieved significantly higher than their counterparts in the control group. Also, Table 2 shows that all the ability groups in the experimental group achieved higher than their counterparts in the control group.

Journals and Portfolios

The experimental group students' reflections in their journals and portfolios indicate that 85% of them felt they were not good at mathematics and 90% of them did not like mathematics when they were in the Senior Secondary

School (SSS). About 85% mentioned teachers as factors that contributed to their failure in or dislike for mathematics. The following student's reflection expressed a typical feeling:

> I do not actually like maths because it involves lot of calculations and thinking. The teacher's laziness made me hate maths since he did not teach us well, and was sometimes not present in class. (Ace)

As many as 83% of the students documented that doing homework, class tests and out-of-class activities individually and in small-group cooperative learning settings helped them to understand mathematics and to be more predisposed to solving mathematics problems. Two students' reflections were typical:

> Learning in group also helped a lot because what you don't understand is what someone understands very well. So we share ideas. Working individually also helped me to know my weak points to be able to bring it out during group discussion. (Cas)

> When we work group test, that one becomes effective because one person will bring an idea, the other too will bring her's and put together and produce something good. In group work people learn new ideas and others tend to benefit. (Ita)

Comparing their attitudes towards mathematics and their achievement in mathematics at the training college and earlier at the SSS, 60% documented that there has been a positive change in their attitude towards mathematics and 71% had experienced an improvement in their mathematics achievement. As many as 84% attributed these changes to the extra group activities and the writing of journals and the developing of portfolios. One student's reflection sums up the feelings of many others:

> I have improved my performance in maths very well and I have interest in it than at first. My attitude towards maths has also improved because I learn and understand it in group discussion. (Bel)

Not all the students were positive about having to work in small groups. While 62% wrote that it enhanced their learning of mathematics, 38% of them thought otherwise.

> Doing homework and tests in a group is very slow and often very disheartening. More often than not, a person is very uncooperative. Others pass insulting comments. (Her)

> Doing homework in groups at times discourages me. This is because your opinion may differ from someone else's own and both of you cannot come to a compromise. If homework is done individually it makes you write what you know without any disagreement anywhere." (Red)

There was an improvement in the achievement of students as well as a positive change in their attitudes towards mathematics. One student's reflection shows how she was motivated to do extra practice on her own.

> There has been an improvement since I came to this college. My attitude towards mathematics is that I am not afraid of mathematics any more as I used to. It has encouraged me so much that I use 30 minutes to work mathematics always. (Mae)

Interviews

Interviews with students revealed several misconceptions students had before the start of the study. Students interpreted the relation $\frac{1}{2}=\frac{2}{4}=\frac{3}{6}$ as increasing the numerator and denominator of $\frac{1}{2}$ by 1 and 2 respectively to get $\frac{2}{4}$ rather than multiplying both numerator and denominator of by 2. Similarly, they explained that the numerator and denominator of $\frac{1}{2}$ was increased by 2 and 4 respectively to get $\frac{3}{6}$ rather than multiplying both by 3. Also, some students could not change mixed numbers to improper fractions correctly. One student could not see anything wrong with her explanation for the conversion, $2\frac{4}{15}+3\frac{1}{3}=\frac{8}{15}+\frac{3}{8}$. To her, the whole number must be multiplied by the numerator and not the denominator, because the product is a numerator.

Discussion

The findings of the study provided multiple indices for gauging students' progress (Huerta-Marcias, 1995) and support many of the positive benefits of alternative assessment. The significant improvement in the performance of only the experimental group on the external tests indicate that the alternative assessment activities significantly increased the students' ability to use problem solving approaches in new situations. The significantly higher performance by the low ability students of the experimental group than their counterparts in the control group on the internal tests indicates that female students with lower achievement in mathematics benefit greatly when exposed to alternative assessment. In particular, it is conjectured that the small-group cooperative learning settings addressed the low ability students' need for individual attention and motivation which were provided by their more able peers.

Students' reflections in their journals and portfolios provided evidence of positive change in their attitudes towards and learning of mathematics (LeMahieu et al, 1995). In particular, the students in the experimental group had the opportunity to organise and initiate their individual and group learning activity. This in turn contributed to their higher achievement which Garcia and Pearson (1994) and Johnson and Johnson (1978) see as the main goal of alternative assessment.

The significant improvement in the performance of the students in the experimental group indicates that if teacher educators in training college were to adopt the alternative assessment form, female students would improve their performance in the first year and some of them will be encouraged to offer elective mathematics in their second and final years. The interviews with the students uncovered their misconceptions of fractions and analysis of students' mistakes revealed what and why they failed to understand. This supports the findings of Erlwanger (1973), Newman (1977) and Alison and Mammino (1987).

The control group's higher performance on the pretests did not give them any advantage in the study. Rather the experimental group surpassed the control group. This indicates that the students exposed to the alternative assessment retained significantly more mathematics concepts and skills taught in the study than their counterparts who were exposed to only traditional assessment. The study suggests that alternative assessment processes can be used to cause female pre-service teachers to integrate mathematics content conceptually.

The issue of the relative practicality of alternative assessment, in terms of time consumption, has been raised by many authors (Gipps, 1994; Linn and Burton, 1994). The study findings indicate that alternative assessment is not more time consuming than traditional assessment on the part of these students. The students in both groups had the same available time as they lived in dormitories on the school campus. The study suggests that students can cope with the time demands of alternative assessment.

Alternative assessment is a new concept in Ghana, and for its effective implementation, teachers will need in-service training in it. The study suggests that such training is worthwhile since teachers will have the means to bring about higher achievement in mathematics and positive attitudinal changes in female pre-service teachers. There is the need for further research to investigate the attitudes of teachers themselves towards the use of alternative assessment processes. Also, further research is needed to investigate whether there are gender differences in the benefits of alternative assessment in mathematics.

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Development of Remedial Method for Teaching Electric Circuits in Secondary Schools

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Abstract

Many senior secondary students experience learning difficulties in physics. This study was to reveal the kind of thinking and understanding about electric circuits of 123 senior secondary Year Two physics students in Cape Coast municipality in the Central Region of Ghana. Also it attempted to develop a remedial teaching method that would be used to remedy any identified misconceptions. An electric circuit Remedial Teaching Method was therefore developed, and its impact was assessed using a non-randomized control pretest/post-test design. The percentages of students who had various misconceptions before and after the treatment were calculated. The findings indicated that the remedial teaching method helped to remedy most of the misconceptions they held. However, a few of the misconceptions were found to be of firm rooting and resisted changes by this teaching method.

Introduction

Recent studies indicate that many secondary school and college students have serious difficulties in understanding fundamental concepts and principles in physics (Arons, 1979, 1980; McDermott, 1984). Apparently many students pass their physics courses without acquiring proper understanding of some of the most fundamental concepts in physics.

`Much interest was therefore generated among science educators in the eighties to investigate the conceptions of physics and identify the ideas held by children of different age groups (Osborne and Wittrock, 1983). Many research findings strongly support the assertion that children of all ages hold their own views about a wide range of physics phenomena prior to their formal learning of science in schools (Gunstone, 1991; Thijs and Berg,

1995). The conceptual framework thus developed by children is mainly based on their intuitions from their interactions with the environment.

These preconceptions provide a sensible and coherent understanding of the physical world from the children's point of view. They are not freak pieces of knowledge or understanding but form part of the conceptual framework developed through their own experiences. Such preconceptions are found to be of firm rooting and resist change by normal classroom teaching (Haggerty, 1988).

Driver (1981, 1982), Shipstone (1984), Joshua & Duph (1987) and Osborne (1981, 1983) are the pioneers among a larger group of researchers probing children's understanding on voltage and current in simple electric circuits. Other studies have identified alternative conceptions held by students on electric circuits and developed strategies to help overcome their difficulties (McDermott & Van-Zee, 1985; McDermott & Shaffer, 1992; Osborne, 1983). Tan 1987), in his study of Upper Secondary Science Students Conceptions on electric current flow, reported that the students seem to hold their own interpretation, and often misinterpreted, modified or rejected the scientific view point that was presented in the classroom.

Miller (1993) discovered that many fifteen-year-old students had very limited understanding of voltage sharing and potential divider. Shipstone and his colleagues (1988) further revealed that a high percentage of fifteen to seventeen-year-old students in several European countries failed to grasp the idea that voltage is proportionately shared between two resistors in a series circuit.

Purpose of the Study

In many countries attempts have been made to develop strategies to help students overcome their learning difficulties in physics. Very little work has been done in Ghana. It is the aim of this study to find the ideas students in Ghana have about simple electric circuits and develop an intervention strategy as a way of helping students to remedy any misconceptions they might hold. Specifically the study addressed the following questions:

1. What misconceptions do Senior Secondary Form Two (SS 2) students have on electric circuits?
2. Would SS2 students who are taught electric circuits using the Remedial Teaching method perform better than those who are taught electric circuits using the traditional approach?
3. Would boys in SS2 perform better than girls in SS2 when they are both taught electric circuits using the Remedial Teaching Method?

Design

As intact classes were used for the experimental and control groups in each of the two schools, a non-randomized pretest/protest design was adopted.

Group A was the experimental group, while group B was the control group. Both groups took the pretest, after which the experimental group A was

given the treatment X, i.e. group A was taught by one of the researchers using the remedial approach while group B did not receive the treatment X, i.e. group B was taught by another researcher using the traditional approach.

At the end of the two weeks (14 periods in all), subjects in both groups in each school were given the posttest, which is similar to the pretest except in wording and in figures. To have a deeper insight into students' thinking, subjects were asked to explain or give reasons for the answer they provided. The data were analyzed by scoring one mark for each correct answer, in accordance with the method used by Tan (1987).

Subjects

The subjects were 55 girls from a girls school and 68 boys from a boys school in the Cape Coast municipality of Ghana. In the girls school, one science class was used as an experimental class with 29 students and the other as the control class with 26 students. In the boys school both the experimental class and the control class had 24 students. In all 123 students were used in the study. The ages of the students ranged from 15 to 19 years with an average of 16.4 years.

Instruments

One main instrument, designed for the study was used in data collection. This is the Electric Circuit Test (EC). The pretest and post-test were constructed to reveal the kind of thinking and understanding which SS2 students had on simple Electric Circuits. The pretest designated as EC1, was a modified form of the one by Tan (1987). The posttest which was of the same standard and designated as EC2 was also developed by the researchers. Each test consisted of six questions with some having sub-questions.

The topic on Electric Circuit was divided into two units. Unit 1 was taught in the first week, taking seven (7) periods of 40 minutes each. Unit 2 was taught in the second week also taking seven (7) periods each of 40 minutes. Each test consisted of six major question items with some having sub items resulting in a total of twelve items.

Teachers for the Study

There were two teachers from the girls school and two from the boys school. in each school one teacher taught the experimental class while the other taught the control class. Though both the experimental and control classes were randomly selected from among the intact science classes in each school, the teachers were the class teachers.

The rationale and procedure for the new teaching method were explained to the teachers who participated in a special workshop for this purpose.

The teachers who were assigned to the control groups, were informed that although they would not take part in the implementation of the new teaching methods, they would participate in the testing activities of the

control groups, and be part of the project. These procedures were intended to secure, as much as possible, equal level of enthusiasm and involvement in both the experimental and control groups. Both groups were involved in the study, and participated in the workshop before the experiment.

Booklet for the Study

Two sets of booklets were prepared well in advance before the units were taught in the class. Question Booklet 1 contained 10 questions based on the entire topic in Unit 1: Questions Booklet 2 also contains 10 questions on Unit 2.

Answer Booklets

There were also two sets of answer booklets, namely Answer Booklet 1 and Answer Booklet 2. Each booklet contained answers with explanations.

Question Booklet 1 and the accompanying answer booklet 1 were supplied to the students at the end of the course in Unit 1. Students responded to the questions during the last 20 minutes of the last lesson for Unit 1. Question Booklet 2 and the accompanying answer booklet 2 were also distributed to the students during the last 20 minutes of the last lesson for Unit 2 course. The students were expected to answer the questions within 20 minutes.

Traditional Approach

The traditional approach used to teach the students in the control group. It involved teaching the units in regular physics course where teaching-learning activity was teacher centred. The teacher prepared his notes and did most of the talking. The teacher answered questions posed by the students. After marking each assignment or class test, the teacher distributed the marked papers to the students to effect the necessary corrections. There was no feedback to enable students correct their misunderstanding or reinforce their understanding. Whenever a student faced difficulties he approached the teacher to explanation. At the end of two weeks the students were given the post-test.

Remedial Teacher Approach

The remedial approach was used to teach the students in the experimental class. Each experimental class formed four discussion groups, each with a leader. After teaching a lesson in a unit, each group was given an assignment to review what had been taught in the class through discussion. During the first 10 minutes of the next lesson, the leader of each group supported by his group members were called upon to explain to the class, their understanding of the concept taught in the previous lesson. By so doing and with the help of the teacher the students were expected to correct their errors and reinforce their understanding.

The most important aspect of the remedial approach is the introduction of the booklets. During the last 20 minutes of the study of each unit in the regular physics course, the teacher distributed the question booklets, one to

each student in the class, along with blank answer sheets. The students then answered the questions individually, writing their answers both on the question-booklet and on the accompanying answer sheets. At the end of the allowed period of time, the teacher collected the answer sheets, leaving for each student the original question-booklet containing the question and the students answers to the questions. After collecting the answer sheets from the students, the teacher distributed among the students the answer-booklets. Each answer booklet contained the feedback and corrective materials, and a short summary of the topic dealt with.

Through the use of the booklets, each students could test himself/herself at the end of the unit of study and immediately reinforce his/her understanding of the topic taught by reviewing the answer booklet with his/her colleagues in the discussion group. This process took place in natural classroom conditions.

All the students in the class received the answer booklet, regardless of their performance on the question-booklets. In that sense, all students in the experimental class received the same undifferentiated treatment. However, the treatment was differential in the sense that the answer booklet had different impact on different students according to their previous performance in the question-booklets. For those who answered a question correctly, the feedback provided by the answer-booklet had a reinforcing effect: the answers, the same information had a corrective value; they could compare their answers with those provided in the booklets, pinpoint the differences between the two, and read the explanatory materials accompanying each sheet, to correct any misunderstanding and compensate for any lack of prerequisite knowledge.

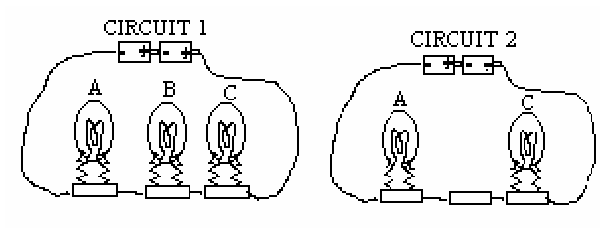
The treatment was differential and remedial in another sense too; the teacher, trough the inspection of the answer sheets he received from the students, obtained immediate and accurate information about the progress of his students. He could easily identify the specific weakness and misunderstanding of each individual student, take corrective action, and do so within a short time after the topic in question had been taught. At the end of two weeks the students were given the post-test. The results of the date analysis are reported below:

Results

Question 1

(a) Circuit 2 was obtained by removing bulb B from circuit 1. Are bulbs A and C lit?

(b) In which of the two circuits is there voltage?

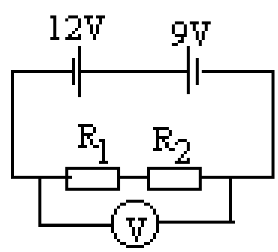


Question one was to find out about students' conceptions about current flow in electric circuits, and whether voltage exists in a battery if the battery is connected to a complete circuit or not. In the pretest, 73% of the boys and 23.1% of the of the boys (both control and experimental) and65.5% of the girls both control and experimental groups chose the correct answer for 1(a) and reasoned that the circuit was not closed and so there was no current in circuit 2. However, in the post-test, only 14.7% of the boys and 23.1% of girls in the control group gave correct answers to 1(a). Also only 14.7% of the boys and 6.9% of the girls in the experimental group got the correct answer. This may be due to the slight change in geometrical pattern of the circuits in the pretest and the post-test. In 1(b) only 14.7% of the boys and 3.8% of the girls in the control groups had the answer correct. However, 70.6% of the boys and 72.4% girls in the experimental group had the answers correct, thus registering an improvement in the post-test.

Question 2

(a) What is the total voltage of the cells?

(b) What is the total reading of the voltmeter?



Questions 2 was to find out about students' conception of total voltage of cells in series and whether the voltages of resistors in series add up to that to that of the source. In the pretest 61.8% of boys and 65.4% in the control and experimental groups had the correct answer to 2 (a) with good

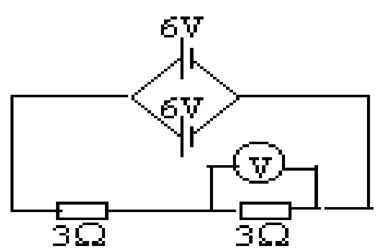
explanation. In the post-test however, only 11.8% of the boys and 11.5% of the girls in the control groups obtained the correct answer and offered good explanation. This is because in the post-test, the two cells in series were opposing. Students failed to realize that when two cells in series are connected in opposition to each other, the voltage oppose. They simply added up without considering the signs. 14.7% of the boys and 13.8% of the girls in the experimental groups had correct response and gave good explanations. Students gave the following explanation: "the cells are in series so their total voltage is the sum of their individual voltages".

In 2(b) 41.2% of the boys and 38.5% of the girls in both the control and experimental groups got correct answer in the pretest. The rest failed to realize that voltage is shared proportionately by resistors in series, and that the voltage across resistors in series add up to give that of the source. In the post-test, only 8.8% of the boys and 3.8% of the girls in the control group had the correct response. However, 20.6% of the boys and 20.7% of the girls in the experimental group had correct response and gave good explanation thus registering an improvement in the post-test.. These students gave explanations such as "the cells are in series and they oppose each other. Therefore the reading of the voltmeter is 12V – 9V = 3V".

Question 3:

(a) What is the total voltage of the cells?

(b) What is the reading of the voltmeter?m



Question 3 was to find out the students' conception about total voltage of similar cells in parallel, and whether similar resistors in series share voltage equally. In the pretest in 3(a), 20.6% of the boys and 77% of the girls in both control and experimental groups reasoned correctly that when a number of similar cells are in parallel, the total voltage is that of one. 38.2% of the boys and 6.6% of the girls used the reciprocal rule which is only applied for resistors in parallel. In the post-test 47.1% of the boys and 53.8% of the girls in the control groups still applied the reciprocal rule of 3 (a). There was no improvement in the post-test for the control groups.

However, there was an improvement in the response to 3(a) by both boys hand girls in the experimental groups. 70.6% of the boys and 75.9% of the girls in the experiment groups realized after the treatment that when similar

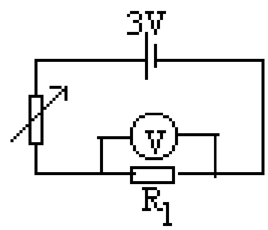
cells are in parallel, the voltage is that of one. In 3(b) 50% of the boys and 11.55% of the girls had wrong conceptions of voltage shared by similar resistors. In the post-test, 15.4% of the girls and 14.4% of the girls in the experimental groups had 3(b) correct.

There was improvement in the girls response, while the performance of the boys rather fell. The answers showed that the wrong conception still existed among the majority of students.

Question 4

(a) What will be the reading of the voltmeter V when the variable resistor R has zero resistance?

(b) As the variable resistor increases its resistance from zero Ohm, what will be the reading of the voltmeter?



Question 4 was to find out about students' conception about the variation of voltage across a resistor if the resistance of another resistor in series is changing.

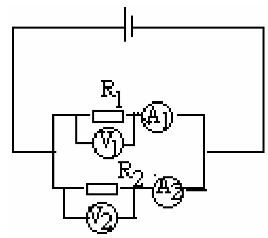
In 4(a) 67.7ã of the boys and 84.6% of girls in both control and experimental groups gave correct responses in the pretest. In the post-test, only 35.3% of the girls and 57.7% of the boys in the control group gave the correct responses. A great majority of boys (82.3%) and girls (82.8%) in the experimental, groups gave the correct response to 4(a) in the post-test. From the above, it is seen that the performance of the control groups after using the traditional method rather fell.

In 4(b), 32.4% of the boys and 15.4% of the girls gave the correct response in the pretest in both control and experimental groups. 23.5% of the boys and 19.2% of the girls said the voltage will not change because the resistance of R1 is not changing. They obviously clinked to the misconception that the voltage across a resistor is the same whether the current remained constant or not. In the post-test, 38.5% of the girls and only 8.8% of the boys in the control group gave correct response to 4(b). This means that the misconception held by the boys remained unchanged while the girls had a great improvement after the treatment.

Question 5

(a) Compare the readings of the ammeters A, and A, given that the resistance C, R is twice that of R.

(b) Compare the reading of the voltmeters V, and V.



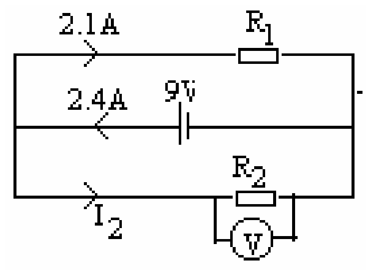
Question 5 was to find out about students' conception on the flow of currents through parallel resistors in a circuit, and whether two unequal resistors in parallel have the same voltage. 41.2% of the boys and 15.4% of the girls in the combined control and experimental groups had correct response to 5(a) in the pretest.20.4% of the boys and 42.3% of the girls in the control groups had correct response to 5(a) in the post-test. While the performance of the girls had improved from the pretest to the post-test, that of boys had fallen. In the post-test 64.7% of the boys and 72.4% of the girls in the experimental group gave correct response.

About twenty percent of the boys and 11.5% of the girls had correct response for 5(b) in the pre-test in the combined control and experimental groups. Most of them maintained the wrong notion that for two resistors in parallel, the one with larger resistance has higher voltage. 35.3% of the boys and 57.7% of the girls in the control groups gave correct response to 5(b) in the post-test while 79.4% of the boys and 100% of the girls in the experimental groups gave correct response to 5(a) in the post-test. This means that the erroneous idea held in the pretest by the girls in the experimental group had been understood and corrected through the treatment. With the boys in the experimental group, 79.4% of them had their misconceptions changed.

Question 6

(a) What is the value of the current 1_2?

(b) What is the reading of the voltmeter?



Question 6 was to find out students' conception about current distribution in sub-circuit, and whether each of the two resistors arranged in parallel with a battery has the same voltage as the battery. For the combined control response in the pretest for 6(a).

In the post-test, 11.7% of the boys and 34.6% of the girls in the control groups gave correct response for 6(a), while 55.9% of the boys and 75.9% of the girls in the experimental groups gave correct response for 6(a). This shows an improvement after the treatment. For 6(b), 55.9% of the boys and 69.2% of the girls in the combined control and experimental groups gave correct response in the pretest.

In the control group, 26.4% of the boys and 50% of the girls gave correct response for 6(b) in the post-test. In the experimental groups, 41.1% of the boys and 75.9% of the girls gave the correct response for 6(b) in the post-test.

Discussion

The intent of this study was to assess the effectiveness of an instructional method which was developed on the basis of careful needs analysis in terms of students background as well as a detailed task of the course under consideration. The results obtained indicate that the use of the materials (i.e. question and answer booklets) and the teaching procedures brought about a substantial improvement in achievement.

The improvement may have been caused by two factors: (a) the quality of feedback provided by the new materials and the instructions followed by students and teachers, (b) the increase in the number of exercises and question that the students in the treatment group received, in comparison with the control group. The experimental design adopted in the study did not allow for immediate assessment of the relative importance of each of these factors after teaching. However, data collected from teachers at frequent meetings during the study indicated that the experimental and control group teachers covered about the same amount of subject matter during the two weeks of the study, and the students in both groups were

exposed to equal times of teaching (7 periods per week). The fact that achievement in the experimental group was better suggest that the type of treatment received and not the quantity of instruction, was responsible for the difference in achievement level between the two groups.

A major difficulty apparently encountered in teaching physics to average and low ability students, in a classroom setting, is that these students tend to interpret their class and laboratory experiences in ways that differ and even contradict the purpose of those activities. Misconceptions brought by the students or created during the learning process in class are often tenaciously held and are difficult to alter through conventional teaching means. These misconceptions are also difficult to detect.

The research study revealed the following among others:

1. In terms of misconceptions there is no significant difference between male and female science students. This finding contrast with earlier findings (Haggert/, 1988; Leboutet-Barrell, 1976) that girls perform relatively poorly in Physics and Chemistry compared to boys. It could be concluded from this that both the low enrolment and performance of girls in science and science activities might not be the result of girls harbouring more misconceptions. Probably, the present method of teaching science, and physics in particular, appeal more to boys and less to girls.
2. The results of the study also indicated that the use of the remedial teaching approach brought about a substantial improvement in achievement.
3. Although there was considerable improvement in achievement of both the female and male students after being exposed to the remedial teaching method, the method seemed to favour the boys more than it did the girls.
4. A certain percentage of both the male and female students still held unto their misconceptions after the intervention. This confirms the fast that some students' misconceptions tend to be pervasive, stable and often resistant to change even after exposure to further instructions (Bell, 1981).

Educational Implication and Recommendation

The findings of this study have the following important education implications and recommendations.

1. The result of this study indicated that it is possible to address this problem of poor performance in a normal classroom setting. This assertion arises from the fact that the remedial teaching approach improved the achievement of average and low ability students used for the study.
2. The approach can be generalized to other areas of school learning, according to its logic premises: (a) content related feedback should

be provided to each student, individually, immediately after he/she finishes the study of a specific topic, (b) students should be asked questions designed to expose misconceptions previously those who are reluctant to engage in mental activity, the feedback provided to the students should include frequent references to the previous concrete experiences of the students (the use of illustrations, pictures or drawings, of actual equipment, etc. is very useful).

3. Science courses, and this is probably true for physics courses in particular, should be carefully designed to match the preparedness in terms of mathematical and logical abilities of the students at which they are aimed.

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A Comparative Study of Rasch and Ziller's Models of Item Analysis

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Abstract

This study compared Rasch and Zillers models in relation to item and person parameters on one hand and guessing tendency on the other. The conditions under which the two models can effectively be applied were highlighted. Based on these conditions, the two models were then compared in line with the various parameters being estimated. It was then concluded that the tendency of a testee to guess (under Ziller's model) is a function of the ability of the testee and the difficulty level of the test items. Similarly, the probability of a correct response to an item (under Rasch Model) is also a function of the difficulty level of that test and the ability of the person responding to the item. This justifies the inter-relationship between Rasch and Ziller's models.

Introduction

Ziller (1957), developed an index for measuring the tendency to guess, and this is based on the principles of the correction for guessing formula defined as:

$$K = R - \frac{w}{c-1} \qquad (1)$$

Where K is the number of items whose answers the candidate knows exactly, R is the total number of items on the test that a candidate "answers correctly", W is the number of items a candidate "answers incorrectly" while C is the number of options for each item.

Ziller's index explains the probability theory of solving the problem of guesswork in any testing procedure, and it is defined as the ratio of the number of guesses estimated to have been made divided by the estimated number of items on which the correct answers were not definitely known.

Illustration

Suppose the total number of guesses made by a candidate is G, and the probability of correct response to an item is $\frac{1}{C}$, while the probability of

incorrect response to an item is $\frac{C-1}{C}$. Then the total number of guesses (both right and wrong) which resulted from guesswork could be defined as:

$$G = \frac{CW}{C-1}. \tag{2}$$

This implies that the number of correct guesses is expected to be $\frac{1}{C}th$ of G, that is, $\frac{W}{C-1}$, which is the same as the second term of the above expression (1). If the total number of guesses is taken to be G, then the above expression (2) can be redefined as

$$W = G\ \frac{(C-1)}{C}. \tag{3}$$

Let G_M be the estimated number of correct responses that resulted from guesswork, i.e. $\frac{W}{C-1}$ plus the number of wrong responses W. Thus

$$G_M = W + \frac{W}{c-1} \tag{4}$$

Similarly, let G_T which is the estimated number of items, whose answers the testee is not sure of, be the sum of items omitted N, the number of wrong responses W, and the estimated number of correct responses that resulted from guesses $\frac{W}{C-1}$. Thus

$$G_T = N + W + \frac{W}{C-1}. \tag{5}$$

By combining equations (4) and (5) above, we could have

$$G_T = N + G_M \tag{6}$$

From these equations (4), (5) and (6), Ziller's index could then be defined as

$$G_Z = \frac{G_M}{GT} = \frac{W + \frac{W}{C-1}}{N + W + \frac{W}{C-1}},$$

$$\text{i.e. } G_Z = \frac{CW}{CW + N(C-1)} \qquad (*) \text{ Module 1}$$

The above model (∗) is one of the contributions of probability theory of solving the problem of guessing in testing. Knapp (1971) used the theory of probability extensively in solving some of the problems of guesswork in testing, although, Ziller (1957) was about the earliest person to apply the principle.

Conditions

It should be noted that:

(i) If a candidate gets all the answers attempted correctly, i.e., for W = 0 no matter how many items are omitted, i.e. $N \neq 0$. Then $G_z = 0$.

(ii) If a candidate does not omit any item, i.e. N = 0, and does not get all answers right, i.e., $W \neq 0$, then $G_z = 1$. The tendency to guess is very high in this respect.

(iii) If a candidate does not omit any item and gets all items right, i.e. N = 0 and W = 0, then G_z is undefined, and so the index of tendency to guess breaks down.

These three conditions might be difficult to achieve in most of the achievement tests - particularly in mathematics. This is because the model does not make room for a testee who works the test items independently and arrives at one of the options given. On the basis of these, it seems therefore, that it would be difficult to pin down a guesser when he/she gets all responses correctly and no items were omitted. However, the higher the value of G_z (as in (ii) above) the more frequently a candidate guesses and so the limit of G_z as N tends to Zero is 1. That is,

$$G_z = \lim_{N \to 0} G_Z = \lim_{N \to 0} \frac{CW}{CW + N(C-1)} = 1$$

To be able to achieve these conditions, it is necessary to talk of the nature of the test items and the characteristic traits of the testees. Within this framework, most testees that resolved to guesswork do this as a result of their inability to solve the test items or because the test items are by their design difficult. Thus, the tendency of a testee to guess is a function of the ability of the testee and the difficulty level of the test items (Alonge, 1990).

Rasch's Model of Item Analysis

Rasch (1960), a Danish Mathematician proposed a model whereby objectively measures of attainment can be achieved. The model is used for test items that are dichotomously scored right or wrong, and is thus applicable to multiple-choice tests and to alternative form of tests.

The basis of the model is the postulate that is possible to speak of the encounter of a person with an item - an encounter which is either successful or unsuccessful, i.e. right or wrong, in terms of just two factors - one specific to the person and the other one specific to the item. These two factors are parameters of the model and are taken to be constant for a given person or item. Thus, the person specific parameter is taken to be constant for a given person regardless of the items that person attempts and the item specific parameter is also taken to be constant for a given item regardless of the person attempting the item (Rasch 1960, 1961; Willmott & Fowles, 1974).

With these background, Rasch's model may be summarised as follows:

1. When a person encounters an item, a single outcome is recorded (i.e. pass or fail), and this outcome depends on:
   (a) a person parameter which is constant for all items attempted by that person;
   (b) an item parameter which is constant for all persons attempting that item.
2. The person parameter is measuring the 'same thing as the item parameter and both parameters are expressed on the same scale.
3. All the items in a test evoke responses from people on the same trait.

The model sets down very simply the above conditions under which objective measurement can be attained.

It may be shown (Rasch, 1968), that these three statements are, in fact, necessary and sufficient conditions for objective measurement to be attained. If the conditions can be satisfied, and if estimates of the item parameters and person parameters can be found, then a great deal (of work) would have been achieved and the benefits accrued enormous, (Wright, 1968; Alonge, 1989, 1990).

According to the model, it could be shown that the estimated value of the item parameter is directly related to the proportion of people in a sample who do not answer the test items correctly and that the estimated value of the person parameter is directly related to a person's total test score. In other words, we could talk of 'item difficulty' and 'person's attainment' in Rasch Model.

Illustration

Let the item parameter d_i be associated with item i, and the person parameter B_υ the associated with each person υ. These parameters determine probabilistically the outcome of the encounter between person υ and item *i*. The basic statement of the model describes the probability of a response xvi by person v to item i, and is defined as:

$$\Pr(x\upsilon_i = 1/(B\upsilon,\ d_i) = \Pr(x\upsilon_i) \ldots \quad (1)$$

Where $i = 1, 2, 3, \ldots, K$ and $\upsilon = 1, 2, 3, \ldots n$

According to the model, when a person's attainment measure is one unit larger than the measure of difficulty for the item attempted, the odd (probability) in favour of a correct reponse goes up by 2.7183 or e, as the model is expressed in exponential term.

Thus, we have from equation (1),

$$\Pr(x\upsilon_i = \frac{e^{\lambda} vi}{1 + e^{\lambda} vi}. \quad (**) \text{ Model 2}$$

Where an observation xvi is recorded as 1, if correct and zero if otherwise, and where

$$x\upsilon_i = B\upsilon - d_i . \qquad (2)$$

It could be seen from equation (2) that the probability of a correct response increases with the attainment of a person ($B\upsilon$), and decreases with difficulty level of the item (d_i). Thus, if zero is recorded for an incorrect response, then.

$$\Pr(x\upsilon_i = 0) = 1 - \Pr(x\upsilon_i), \text{ and therefore}$$

$$\Pr(x\upsilon_i = 0)/B\upsilon d_i) = 1 - \frac{e^{\lambda} v_i}{1 + e^{\lambda} v_i} = \frac{1}{1 + e - vi}$$

Combining equation 1, 2, & 3, we have

$$\Pr(x\upsilon_i/B\upsilon d_i) = \frac{e(Bv - di)}{1 + e(Bv - di)} \qquad (***) \text{ Model 3}$$

where (***) is the expanded form of Rasch's Model defined above.

Conditions

In a special case where $B\upsilon = d_i$, then $\lambda v_i = 0$ and $\Pr(x\upsilon_i = 1/B\upsilon, d_i) = 0.5$. This implies that there is a 50% chance of success for a person υ with attainment $B\upsilon$ attempting item i with difficulty d_i.

In order words, if a person is presented with an item, the difficulty of which matches his attainment (i.e. $B\upsilon = d_i$), the probability of the person getting the item correctly is 0.50 (i.e. 50% chance). If the person's attainment is greater than the item's difficulty (i.e., $B\upsilon > d_i$), then the probability of a correct response would be greater than 0.50; and if less, then the probability of correct response would be less than 0.50. In summary, this probability increases or decreases depending on the positive or negative distance of $\lambda\, \upsilon_i$ from zero, i.e. according to the differences between $B\upsilon$ and d_i as defined in equation (2) above.

Comparison of the Models

(i) Ziller's index of tendency to guess (G_z) is defined as the ratio of the number of correct guesses estimated to have been made divided by the estimated number of items on which the correct answers were not definitely known. That is

$$G_z = \frac{G_M}{G_T} = \frac{W + \frac{W}{C-1}}{N + W + \frac{W}{C-1}} = \frac{CW}{CW + N(C-1)}$$

(iii) while Rasch's model believed that the estimated value of the item parameter, (i.e., item difficulty) is directly related to the proportion of people in a sample who do not answer the test items correctly, and that the estimated value of the person parameter (i.e., person's attainment) is directly related to the person's total score. Thus, mathematically, we have from the above:

P value is $(d_i) = \frac{N_W}{N_t}$ and D value is $(B\upsilon_i) = X\upsilon$

By correlating the item score with the total test score, item discrimination value can be obtained. In other words, item discrimination has a direct relation with person's attainment. Within these two concepts, studies (Rasch, 1960; Willmot, et al, 1974; Fray, et al 1977; Wainer et al 1980 and Nenty 1985) have shown that, the probability of a correct response to an item is a function of the difficulty level of that test item and the ability of the person responding to the item (i.e. $\Pr(x\upsilon_i = 1) = f(B\upsilon, d_i)$

As earlier pointed out (under Ziller's model) the tendency of a testee to guess is also a function of the ability of the testee and the difficulty level of the test item (i.e. $G_z = f(B\upsilon, d_i)$. This is where Rasch's and Ziller's models come together or are related, i.e. $(\Pr(X\upsilon_i = 1) = f(B\upsilon, d_i) = G_z$.

With the mathematical illustrations of the two models (*) and (**) they are highly related, in the sense that, their indices are functions of the difficulty levels of the test items and the person's attainment. However, Wainer, et al (1980) concluded that the raw score (number correct) is a sufficient statistic for estimating person parameter and item score is a sufficient statistic for estimating item parameter. According to them, both parameters are in the logistic metric and are referred to as measurement in "Logists". These indices could be estimated for each of the models. Since one lays emphasis on the difficulty level and person's attainment and the other on guesswork, students' performances on both models using achievement tests could be compared empirically.

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An Investigation into Factors that Influence Teachers' Content Coverage in Primary Mathematics

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Abstract

This paper reports a survey that investigated the influence of teacher characteristics and organisational factors on teachers' coverage of the content of primary school mathematics. A questionnaire was administered to measure teachers' knowledge of mathematics and other characteristics. The chi-square (χ^2) test conducted on the data obtained from 137 primary school teachers in the Winneba district who participated in the survey, showed a significant difference (with $\chi^2= 4.238$, $p < .05$) between the content coverage ratings of teachers with O' level mathematics qualification, and those without. The higher rating for coverage of topics in basic number concepts was recorded by teachers with no O' level mathematics qualification. The result suggests O' level GCE qualification in mathematics does not make any significant impact on teachers' coverage of topics in basic number concepts, which is the most covered content area in the primary mathematics curriculum. O' level GCE qualifications, on their own, lead mainly to general attainments in the subject. But, as the results have indicated, this makes very little difference in the primary teachers' content coverage, which is a good determinant of students' learning. Therefore in an educational system, like the one in Ghana, where teachers possess low teaching qualifications, it would be more useful if in-service courses are planned to increase not only the teachers' knowledge of content of mathematics, but also of their knowledge of pedagogy and learners' cognition.

Introduction

The Education of Basic School Teachers and their Weak Knowledge in Mathematics

Before the educational reforms began in 1987, initial training of primary school teachers in Ghana was done at two levels – the post-middle or junior-secondary school (JSS) level, and the post senior-secondary level. The programmes offered at both levels led to equivalent qualifications, that is, *Teacher's Certificate 'A'*. In an international study carried out in the 1980s, such programmes were described as *'secondary level'* initial teacher training programmes (Gimeno and Ibanes, 1981). Today, even though teachers are trained only at the post senior-secondary level, and the post middle/JSS

programme has been phased out, the content or coverage of the initial teacher training programme is yet to be changed.

The trainee, by the end of his/her training, was expected to have an academic attainment which was equivalent to that of O-level General Certificate of Education (GCE) in the nine or ten different subjects studied, together with Education and Practical Teaching - the subjects being English Language, Ghanaian Language, Mathematics, General Science, Agricultural Science, Physical Education, Art, Music and Social Studies. Owing to the emphasis the programme placed on the development of the trainees academic and intellectual capabilities, professional studies courses which dealt with the theoretical and practical aspects of teaching were not given due attention. It can be argued in the light of these that at the time of leaving college many Ghanaian primary school teachers have no secure command of the subject matter to be taught and their competence in teaching primary school pupils mathematics is low.

Notwithstanding this background, not much provision was made for teachers, in terms of in-service education, during the change over to the teaching of new mathematics curriculum that occurred in the late 1970s with the introduction of the Ghana Mathematics Series textbooks.

GNAT's Attempt to Improve Basic School Teachers' Weak Knowledge in Mathematics

In response to the national outcry on the poor pupil performance in mathematics, and criticisms about teachers' classroom practices, the Ghana National Association of Teachers (GNAT) launched a campaign to improve the academic competence of the bulk of school teachers without O' level GCE qualifications. With the cooperation of the Ghana Education Service (GES), the GNAT set up in all regional capitals in the country, *'GCE O' level Centres'*. The centres, which were started in 1990, provided revision or preparatory courses for O' level GCE examinations in all school subjects. Teachers with no O' level GCE qualifications were encouraged to pay from their own resources to take the courses which were organised after school hours. The courses spread to a number district centres. A report in the newsletter of the GNAT, *'The Teacher'*, indicated that the work of the centres were yielding good results and that most of the teachers who took advantage of the centres "were able to obtain either distinction, first or second divisions" (*sic*) (GNAT, 1992).

But a study commissioned by the Ghana Ministry of Education (1992) on '*Factors militating against effective teaching and learning in primary schools*' pointed out that

> in spite of the injection of inputs, (such as textbooks, stationery, and other teaching and learning equipment and materials) into schools, and in spite of the orientation and other in-service courses organised for teachers to improve the teaching and learning processes in schools,
>
> i) effectiveness of public schools remains low, and
>
> ii) achievement of public primary schools is low.

In other words, although there is no system of national testing, the level of pupils' attainment in subjects taught at the primary level, particularly in English and mathematics, was found to be unacceptably low. The concern about the poor pupil performance in English and mathematics urged the Ministry in 1992 to institute a test, designated "*criterion-referenced test*[1]" (CRT), to determine the extent of pupils performance in these subjects. The criteria used in this test were scores that pupils have to attain to be described as having achieved mastery of the knowledge and skills specified by the official primary curriculum.

The test involved 12,000 pupils and 233 test administrators drawn from all regions across the country. Four content areas were assessed in mathematics. The areas include basic number concepts, number operations, story problems (that is, data handling, commercial arithmetic and use of numbers), and geometry and measurement. The test which comprised 100 items from the four content areas took 140 minutes. A summary of the results of the CRT has been presented in Table1.

Table 1. Summary of the results of the criterion-referenced test in mathematics, 1992

Mastery Level (or proportion of descriptions of performance mastered)	**Criterion** (i.e. Label for Criterion Descriptions)	Number of **Pupils Meeting Criterion** out of 12,000	Percentage of **Pupils Meeting Criterion**
55% or above score	Good	127	1.1 %
50% or above score	Average	241	2.1 %

The CRT results (Table 1.1) indicate that only 1.1 per cent of the pupils demonstrated mastery over at least 55 per cent of the descriptions of performance that Primary 6 pupils are expected to attain, and only 8.1 per cent of pupils have attained mastery over at least 40 per cent of the content of the primary mathematics curriculum. The results suggest that over 90 per cent of the pupils do not achieve mastery of 40 per cent of the knowledge and skills (specified by the official primary curriculum). The pupils' performance on the four content areas were summarised as

> Pupils scored highest on subsections on mathematical operations, and on geometric shapes. They scored lowest on story problems. More than 50% of the pupils responded correctly to items on adding two digits, subtracting two digits, and on finding the perimeter of a geometric shape. Less than 25% on items related to the number line, percentages, rounding numbers, use of < and > symbols, square roots, multiplying with mixed fractions, and on story problems (GMOE/PREP, 1994).

The Problem and Research Questions

The educational authorities' claimed that the poor pupil performance in the subject was due to deficiencies in primary teachers' efficacy in the teaching of mathematics. In identifying the deficiencies, *The National Planning Committee for the Implementation of School Reforms* (NPCISR) stated that

... most teachers

a) are not confident and competent enough to facilitate the learning of mathematics;
b) cannot use the prescribed syllabus and official textbooks;
c) cannot apply the appropriate methods to teach mathematics in the primary schools;
d) rely on past years' expanded schemes of work to teach pupils; and,
e) have a negative attitude towards mathematics (GMOE / NPCISR, 1993).

The educational administrators claimed the poor performance of primary pupils in the subject was due to lack of confidence and competence, on the part of teachers, to teach the content of the materials and use the prescribed methods, to facilitate the learning of mathematics in primary schools. It was argued that teachers rely mainly on past years' expanded schemes of work to teach because they are incapable of using the prescribed syllabus and official textbooks.

Even though frame' factors like the physical setting of schools, timetable arrangements, number of lessons in the year, grouping, and class size, are sometimes cited, they are not regarded as crucial as those directly related to the implementation of the curriculum at the classroom level. Other reasons adduced for the poor performance of pupils in the subject include the lack of qualified teachers, lack of in-service training, inadequate supply of textbooks and other instructional materials and the 'loaded' syllabus (Akyeampong, 1991).

To claim that the low pupils' attainment in the subject is a reflection of teachers' inability to teach a substantial part of the content of the curriculum, is to assume that the two aspects of the curriculum - content taught and content learned - are not only identical, but are also insufficient. That is, far less than what is expected, or expressed by the official curriculum. This assumption is questionable since what is learned by pupils in the curriculum is influenced not only by teachers but also by such frame factors as the physical setting of schools, timetable arrangements, class size, inadequate supply of textbooks and other instructional materials. In addition, the curriculum is affected also by the structure and content of textbooks, to say nothing about pupil capabilities.

Since it is not possible in one study to examine all the above factors and the extent to which they affect student performance in mathematics, the study investigated

i. Whether or not teachers saw the low pupils' attainment in the subject as a reflection of their poor coverage of the content of the curriculum.

ii. Teacher characteristics and organisational factors that make a difference in teachers' coverage of the content of the mathematics curriculum at the classroom level?

The teacher characteristics considered in the study are sex, class, teaching experience, and O' level mathematics qualification; and the organisational factors are size of teacher's class, time allocated for mathematics teaching, and participation in in-service education.

Literature

Teachers' Content Coverage and Students' Learning

Barr (1987) asserts that "although content coverage serves as a major construct in some theoretical formulations, it has received little theoretical treatment in its own right. Further, as used descriptively, it refers to a complex of related conditions". According to Porter *et al.* (1979), 'content coverage', can be distinguished into 'content covered' and 'content emphasised'. The first -content covered - refers to actual counts made of concepts introduced or the range of content (or skills) actually taught (McDonald, 1976). Measures of content emphasised identified in the literature includes such proxies for content coverage as time allocated to content, textbook length or number of pages in textbook devoted to concept or topic (Good et al. 1978; Barr, 1987; Freeman and Porter 1989).

The empirical literature on content coverage can be separated into two main strands. On one investigators were concerned with "the influence of the curriculum on learners' opportunities to learn concepts measured by achievement tests" (Barr, *op cit.*). Most of the studies in content coverage have treated coverage as a condition that acts upon learning autonomously. In these studies, the researchers were concerned with the influence of content coverage (which is analogous to 'opportunity learn') on learners' achievement. Other researchers have considered coverage as a reflection of a complex set of instructional components that jointly affect learning.

Both studies that have explored the influence of content coverage on learners' achievement and studies which have been concerned with content coverage as part of a complex instructional component that influences the whole curriculum, have used similar methods to estimate the extent of coverage. In one study, teachers were asked to judge whether they had promoted the learning of (that is, whether their students had had the opportunity to learn) the content exemplified by given test items. In the other study, teachers were asked to evaluate their coverage of content by indicating for test items whether or not they had spent very little to very much time teaching the relevant content (Husen, 1967; Chang and Raths, 1971).

Husen (1967) found a substantial relationship between teacher reported content coverage (i.e. opportunity to learn) and students mathematics achievement. Chang and Raths (1971) also found that differences in achievement between middle-class and lower-class schools were associated with the degree of emphasis on content as reported by teachers. International summaries of research on relationship between content coverage and achievement demonstrate that students learn the content of

the curriculum they are taught; the more they are taught, the more they learn (Oxenham, 1992).

Teachers' Knowledge of Mathematics and Its Impact on Students' Learning

No one questions the idea that what a teacher knows, or what a teacher's qualification is in a subject, is one of the most important influences on what is done in classrooms and ultimately on what students' learn. However, there is no consensus on what critical knowledge is necessary for teachers to ensure that the students' learn mathematics successfully (Fennema & Franke, 1992).

Different beliefs about the influence of teachers' knowledge on students' learning have been identified (Ball, 1988; Post, Harel, Behr, & Lesh, 1991). Some academics in mathematics believe that since one cannot teach what one does not know, teachers must have in-depth knowledge not only of the specific mathematics they teach, but also of the mathematics that their students are to learn in future. These mathematicians see only content knowledge as what is necessary for optimum student learning of the subject. Some mathematicians too believe that knowledge of how students think and learn is vital knowledge for teachers. But most mathematics educators today believe that knowledge of general pedagogical principles is a necessary component of teachers' knowledge.

In spite of the beliefs in the importance of mathematical knowledge and the evidence that some teachers do not have adequate knowledge of mathematics (Brown, Cooney and Jones, 1990), research has provided little support for a direct relationship between teachers' knowledge of subject matter content and students' learning completed (Fennema & Franke, 1992). Recent studies, which involved also other components of teachers' knowledge of the subject – pedagogical knowledge and learners' cognitions – reported substantial relationship between teachers' knowledge and students' learning.

In most of the studies that investigated the relationship between student learning and teachers' knowledge however, no attempt was made to measure what teachers knew about mathematics or to ascertain accurately the mathematics covered in the various courses completed (Fennema & Franke, 1992). What were often used as proxy measures for knowledge were the teacher's highest qualification in the subject – i.e. GCE, Diploma, or Degree, the number of university courses taken in the subject, and the teacher's performance on standardised tests. In this study therefore, *O' level mathematics qualification* will be used as the proxy measure for the basic school teacher's knowledge of mathematics.

Teachers' Knowledge, and Other Frame Factors as Predictors of Content Coverage

Studies in which coverage has been viewed as an element of instruction have been concerned with the determinants of coverage, and with its effect manifest in learning. Dahlloff (1971) argues that teacher characteristics and frame conditions – the physical setting, school administration, grouping, class size, structure and objectives of the syllabus, school year,

and number of lessons in the year – set temporal and spatial limits on educational processes including content coverage.

As it has been observed from above that content coverage is a good determinant of students' learning, it will be very useful to know which factors affected this important variable in the implementation of the curriculum. In this study therefore, a major frame condition – teachers' knowledge of his subject matter – and other frame conditions are explored to see the extent to which they influence teachers' coverage of the mathematics curriculum in the Ghanaian school context.

Methodology

The Winneba District was selected as the source of schools and teachers for this study. The district was used for this study because it had conditions that made its educational provisions typical of that of the whole country, and offered all the opportunities that were required to carry out a study of this kind. The district is divided into five Educational Circuits - Winneba, Senya, Awutu, Bontrase and Bawjiase circuits. Based on the proportion of schools in each circuit, forty-four schools were used for the study.

Instrument

The determinant of instructional content, which was used to estimate the extent of teachers' coverage of the curriculum at the classroom level, was measured by the questionnaire. Content covered was operationalised as the time (expressed in weeks, or six 30-minutes periods) spent on teaching content in topics.

The questionnaire also measured personal characteristics of teachers and organisational factors that were considered likely to influence the amount of content covered during instruction. The personal characteristics were teacher's sex; length of teacher's teaching experience; teacher's GCE O'Level qualification in mathematics; and teacher's participation in in-service education and training. The organisational factors included teacher's class and size of teachers' class.

Twenty-five items were structured to elicit responses along a three-point scale - a good deal of teaching, some teaching and no teaching - to indicate whether the teacher had done on topics in the official curriculum more than two weeks teaching; some, but not more than two weeks; or done no teaching at all. The items were intended to obtain information on teacher's coverage and emphasis on topics in the official primary mathematics curriculum. Teachers were made to examine topics listed from the official textbooks and to indicate by a tick on the three-point scale the extent to which they have covered each topic. (See Appendix for details of the questionnaire.)

To treat these features, characteristics or factors as variables, each was appropriately quantified.

Validity and Reliability

Ten teacher trainers, who were pursuing further studies in mathematics education and science education in the School of Education of the University of Leeds, were asked to complete the questionnaire. The purpose was mainly to detect lack of clarity in the phrasing of the questions, and to give indication of the time needed for its completion. They observed the respondents would require between 30 to 40 minutes to complete the questionnaire. No changes were deemed necessary in the instruments.

Administration of Instruments

The instruments were administered to teachers in the forty-four schools selected for the study. The number of teachers making responses to items in the questionnaires have been presented in Table 2.

Table 2 Analysis of respondents to items in the questionnaire

Item/variable label	Number of teachers returning questionnaires	Number of teachers completing questionnaires	Completions as % of teachers returning questionnaires
Content Coverage	137	137	100
Teacher's sex	137	137	100
Teacher's class	137	127	93
Length of teacher's teaching experience	137	137	100
GCE O' level mathematics qualification	137	112	82
Size of teacher's class	137	137	100
Time allocated for mathematics teaching	47	44	94
Participation in in-service education	137	137	100

The data obtained from the questionnaires were coded and quantified, and then recorded on data summary sheets, following the format required by the Statistical Package for the Social Sciences (SPSS) computer software, described by Youngman (1979) and Bryman & Cramer (1990). The data were subsequently entered into the computer and the SPSS was used in the statistical analysis.

Analysis of Data

The response options on the extent to which teachers covered topics in their instruction were scored as follows: "0" no teaching on topic; "1" some teaching on topic; "2" a good deal of teaching on topic. The mean content coverage scores for the teachers were computed for each topic.

To investigate whether or not there is a relationship between teachers content coverage and the factors being investigated, the teachers' mean content coverage scores were calculated. Furthermore, to ensure the

results obtained for the teachers' mean content coverage can be compared with students' learning in the subject, the topics rated were grouped into five categories to match those employed in the "1992 criterion referenced tests" given to primary pupils across the country. The five categories were labeled as:

- commercial arithmetic and data handling;
- measurement concepts;
- basic number and fractional concepts
- number operations; and
- geometric concepts

The topics grouped under each of the five categories can be seen in Table 3.

Table 3 Topic Categories Used for the criterion reference test

Category	Topics grouped under category
Commercial arithmetic and data handling	ratio/proportion, money, percentages, graphs, averages, interest, chance, etc.
Measurement concepts	length, capacity, weight, area, volume, time; etc.
Basic number and fractional concepts	sets and numbers, numbers and numerals, place value, fractions, decimals, integers, rational numbers, , etc.
Geometric concepts	geometry 1, geometry 2, angles, movement geometry, , etc.
Number operations	number plane/lines; the arithmetic operations on numbers, fractions, decimals, integers, rational numbers, etc.

Composite ratings for content coverage for the various categories were calculated for each teacher and the mean scores obtained were taken as the measures of the teachers' coverage of content in each category. The composite mean content coverage ratings for the five areas of content are presented in Table 4.

Table 4 Mean teachers' content coverage ratings for the five areas of content

Area of content	Mean	Standard Deviation	No. of teachers making responses
Geometric concepts	.93	.61	116
Commercial arithmetic and data handling	.94	.72	98
Measurement concepts	.91	.60	131
Number operations	1.63	.55	126
Basic number and fractional concepts	1.78	.32	137

The teachers' mean content coverage ratings were further analysed in respect of *personal characteristics* - teacher's sex, length of teaching experience, O' level mathematics qualification, participation in in-service education; and *organisational factors* - teacher's class, and teacher's class

size. The mean content coverage ratings obtained for the five areas of content presented in teachers' actual classroom teaching with respect to each of the personal and organisational characteristics can be seen in Table 5.

Table 5 Mean content coverage ratings by their personal characteristics and organisational factors

	Basic number concepts	Commercial arithmetic and data handling	Geometric concepts	Measurement concepts	Number operations
Teacher's sex					
female	1.85	.81	.90	.89	1.70
male	1.73	1.00	.95	.93	1.58
Length of teacher's teaching experience					
more than 3 years	1.81	.97	.94	.93	1.67
not more than 3 years	1.69	.89	.89	.87	1.52
Level of teacher's class					
lower primary	1.86	.82	.91	.79	1.90
upper primary	1.74	.97	.94	.97	1.51
Size of teacher's class					
not more than 35 pupils	1.79	.86	.92	.98	1.68
more than 35 pupils	1.77	1.00	.94	.87	1.59
Teacher's participation in in-service					
in-service courses ≤ 2	1.80	.90	.93	.92	1.64
in-service courses > 2	1.59	1.25	.93	.87	1.53
Teacher's Knowledge in mathematics					
with no O'-level qualification	1.79	.94	.88	.84	1.67
with O'-level qualification	1.76	.96	.98	1.00	1.59

To verify whether or not the differences in teachers with respect to the personal characteristics, and with respect to the organisational factors, have any effect on their content coverage required an appropriate statistical test. To do this the mean scores were recoded using the criteria indicated in Table 6. Thus making it possible for the data being examined to be presented in a cross tabulation.

Table 6. Criteria for recoding teachers' mean rating

	Criteria for coverage		
	Not covered or Mentioned	*Covered*	*Emphasised*
	Teachers' mean rating from 0 to 0.49	Teachers' mean rating from 0.50 to 1.49	Teachers' mean rating from 1.5 to 2
Score for Teachers' mean rating of coverage	0	1	2

As the data was measured at nominal level and the variables - content coverage and the characteristics - are unrelated, the appropriate test that these conditions were found to meet was the chi-square test. For details about the assumptions required by non-parametric tests of difference, and

how to carry out such tests, refer to sources (Siegel, 1956; Coolican, 1990; Norusis 1991; Robson, 1993).

The chi-square (χ^2) values for the test for differences between teachers' content coverage ratings with respect to their personal characteristics and organisational factors were calculated with the aid of the SPSS computer software and the results are presented in Tables 7 – 11.

Table 7. Mean ratings and χ^2 values for coverage of basic number and fractional concepts by personal and organisational characteristics

	Number of teachers	Mean ratings	Pearson's χ^2 value	Significance
Teacher's sex: female	51	1.85	2.650	-
male	83	1.73		
Length of teacher's teaching experience:			1.077	-
more than 3 years	101	1.81		
not more than 3 years	33	1.69		
Level of teacher's class: lower primary	43	1.86	1.846	-
upper primary	91	1.74		
Size of teacher's class:			0.312	-
not more than 35 pupils	56	1.79		
more than 35 pupils	78	1.77		
Teacher's participation in in-service			3.729*	$p < .05$
in-service courses ≤ 2	119	1.80		
in-service courses > 2	15	1.59		
Teacher's qualification in O' level mathematics:			4.238*	$p < .05$
without qualification	71	1.79		
with qualification	63	1.76		

Table 8 Mean ratings and χ^2 values for coverage of commercial arithmetic and data handling by personal and organisational characteristics

	Number of teachers	Mean ratings	Pearson's χ^2 value	Significance
Teacher's sex: female	27	.81	3.227	-
male	69	1.00		
Length of teacher's teaching experience:			1.012	-
more than 3 years	86	.97		
not more than 3 years	28	.89		
Level of teacher's class: lower primary	17	.82	2.024	-
upper primary	79	.97		
Size of teacher's class:			0.894	-
not more than 35 pupils	36	.86		
more than 35 pupils	60	1.00		
Teacher's participation in in-service			2.893	-
in-service courses ≤ 2	84	.90		
in-service courses > 2	12	1.25		
Teacher's qualification in O' level mathematics:			0.198	-
without qualification	47	.94		
with qualification	49	.96		

Table 9 Mean ratings and χ^2 values for coverage of geometric concepts by personal and organisational characteristics

	Number of teachers	Mean ratings	Pearson's χ^2 value	Significance
Teacher's sex: female	39	.90	0.403	-
male	75	.95		
Length of teacher's teaching experience:			1.012	-
more than 3 years	86	.94		
not more than 3 years	28	.89		
Level of teacher's class: lower primary	33	.91	0.058	-
upper primary	81	.94		
Size of teacher's class:			1.748	-
not more than 35 pupils	50	.92		
more than 35 pupils	64	.94		
Teacher's participation in in-service			0.203	-
in-service courses ≤ 2	99	.93		
in-service courses > 2	15	.93		
Teacher's qualification in O' level mathematics:			0.081	-
without qualification	59	.88		
with qualification	55	.98		

Table 10 Mean ratings for coverage of measurement concepts by personal and organisational characteristics

	Number of teachers	Mean ratings	Pearson's χ^2 value	Significance
Teacher's sex: female	47	.89	4.785	-
male	81	.93		
Length of teacher's teaching experience:				-
more than 3 years	98	.93	0.538	
not more than 3 years	30	.87		
Level of teacher's class: lower primary	39	.79	6.290*	p < .05
upper primary	89	.97		
Size of teacher's class:			1.131	-
not more than 35 pupils	53	.98		
more than 35 pupils	75	.87		
Teacher's participation in in-service			0.985	-
in-service courses ≤ 2	113	.92		
in-service courses > 2	15	.87		
Teacher's qualification in O' level mathematics:			0.155	-
without qualification	70	.84		
with qualification	58	1.00		

Table 11 Mean ratings for coverage of number operations by personal and organisational characteristics

	Number of teachers	Mean ratings	Pearson's χ^2 value	Significance
Teacher's sex: female	47	1.70	3.212	-
male	77	1.58		
Length of teacher's teaching experience:			2.516	-
more than 3 years	93	1.67		
not more than 3 years	31	1.52		
Level of teacher's class: lower primary	39	1.90	14.350***	p < .001
upper primary	85	1.51		
Size of teacher's class:			0.870	-
not more than 35 pupils	51	1.68		
more than 35 pupils	71	1.59		
Teacher's participation in in-service			2.402	-
in-service courses ≤ 2	107	1.64		
in-service courses > 2	15	1.53		
Teacher's qualification in O' level mathematics:			1.375	-
with no qualification	66	1.67		
with qualification	58	1.59		

Findings

With regard to coverage of topics in basic number concepts (Table 6), a significant difference (with $\chi^2= 3.729$, and $p < .05$) was found between the mean coverage ratings of teachers with a good deal of participation in in-service courses and teachers without. The higher mean rating for coverage of topics in basic number concepts being recorded by teachers with a good deal of participation in in-service courses. A significant difference (with $\chi^2= 4.238$, and $p < .05$) was found also between the mean coverage ratings of teachers with O' level mathematics qualification, and those without, the higher mean rating for coverage of topics in basic number concepts being recorded by teachers with no O' level mathematics qualification. With regard to coverage of topics in measurement concepts (Table 9), a significant difference (with $\chi^2= 6.290$, and $p < .05$) was found between the mean coverage ratings of teachers teaching in lower primary classes and those teaching in upper primary classes. The higher mean rating for coverage of topics in measurement concepts were recorded by teachers in upper primary classes. In respect of coverage of topics in number operations (Table 6.10), a highly significant difference (with $\chi^2= 14.350$, and $p < .001$) was found between the mean coverage rating of teachers teaching in lower primary classes and those teaching in upper primary. Again the mean coverage ratings, on this occasion for topics in measurement concepts were recorded by teachers in upper primary classes. No significant differences were found between the mean coverage ratings of topics in 'commercial arithmetic and data handling' and 'geometric concepts' presented in Tables 7 and 8 respectively.

Discussion of Results

An attempt was made to explain why the three teacher characteristics - level of teachers' class, teachers' participation in-service, and teachers' O' level GCE qualifications - resulted in differences in the amount of coverage given to topics. Teachers teaching in upper primary classes were found to give more attention to topics in measurement concepts than those teaching in lower primary classes, because most of the exercises on measurement involve units of measurement, finding their equivalencies and carrying out computations on the units, which are taught mainly at the upper primary level.

The explanations found for the reasons why teachers with a good deal of participation in in-service courses were found to give more attention to topics in basic number concepts than teachers with little or no participation were trivial and therefore not stated here. This was mainly because about 90 per cent of the in-service courses organised for primary teachers in the period under review were not directed towards the teaching of primary mathematics.

The mean ratings of coverage of topics in basic number and fractional concepts observed for teachers with O' level GCE qualifications in

mathematics, and those without, were 1.79 and 1.76 respectively (see Table 6). The higher mean coverage rating was observed for 53 per cent of the teachers who had no such qualification. No reasons, however, were found to explain why teachers without O' level GCE qualifications in mathematics gave more attention to topics in basic number concepts than their counterparts with the qualifications. But no significant differences were found between the two categories of teachers in their coverage of the remaining areas of content.

It showed that teachers without O' level GCE qualifications in mathematics gave more attention to teaching topics in basic number concepts than teachers with the O' level GCE qualifications in the subject. These results suggest O' level GCE qualification in mathematics does not make any significant impact on teachers' coverage of content of the primary mathematics curriculum.

The results are not however surprising because the content of the O' level examination is not identical to the content of the primary mathematics curriculum. The content of the former is not only complex but also include several topics that are not included in the primary curriculum. Besides, my personal observation of courses organised at the *GCE O' level Centres* indicated that the activities at the centres, as the name suggests, were all geared toward the examination. The content of the courses were never designed to cover primary curriculum matters and pedagogical issues, and the course organisers at the centres did not teach in ways in which teachers are expected to teach pupils at the primary level.

Implications for Teacher Education Programmes

The findings have implications for the usefulness of O' level GCE qualifications in improving the teaching of mathematics. It also has implications for what should constitute an appropriate *content of core mathematics* for all teachers in further teacher education programmes.

Since teachers without O' level GCE qualifications in mathematics gave more attention to topics in this important area of content than their counterparts with the qualifications, but did not differ very much from them in their coverage of the other areas of content, the assumption that the teaching of the subject will improve students' learning when teachers obtain O' level GCE qualifications is doubtful.

O' level GCE qualifications, on their own, lead mainly to general (or academic) attainments in the subject. But as the results have indicated, this makes very little difference in the primary teachers' content coverage which is a good determinant of students' learning. If the emphasis on *O' level* (or *core* mathematics) was to make the teachers increase their coverage of the primary curriculum in areas which were given inadequate attention (i.e. geometry, measurement, and commercial arithmetic and handling data), then as the results indicate, it has failed to do so.

Therefore in an educational system, like the one in Ghana, where teachers possess low teaching qualifications, it would be useful if such core courses

are planned not only to increase the teachers' knowledge of content of mathematics, but also of their knowledge of pedagogy and learners' cognitions. Pedagogical knowledge includes teachers' knowledge of procedures, such as effective strategies for planning, classroom routines, behaviour management techniques, classroom organisational procedures, and motivational techniques. Learners' cognitions includes knowledge of how students think and learn and, in particular, how this occurs within specific mathematics content.

Core courses should also provide teachers in further education with opportunities to study and work through the school curriculum that they will be implementing. This will enable them understand changes which had occurred since their own college days and also to anticipate difficulties that pupils are likely to encounter in learning the subject.

Institutions responsible for the further education of teachers should therefore ensure the nature of the core courses they offer are directed not only towards the development of teachers' knowledge of content, but also to the development of their pedagogical knowledge and their knowledge of learners' cognitions. That is, the institutions should see to it that the courses in mathematics are designed so as to enable a good mastery of "relevant" subject-matter content with its associated pedagogy, and not to put undue emphasis on "high" subject-matter content which has little relevance to classroom instruction.

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Notes

1 The term suggests a test in which a pupil's performance on given assessment task is judged against a set of descriptions of knowledge and skills (that is, the criteria defined by a given syllabus). In a criterion referenced test, the term '*criterion*' can refer to a description of the knowledge and skills possessed by the learner, or the score which has to be reached to qualify for a description (Foxman, Ruddock, and Thorpe, 1989**).** In this test, there was an attempt to use the latter definition but there were no clear descriptions of knowledge and skills (or criteria).

2 The expanded scheme of work is the name coined for the teacher's lesson plan. The plan which includes seven columns for items like date, topic, objectives, references/teaching materials, core points, expression work and remarks, was recommended by the Ministry to be followed by all teachers.

Appendix

INSTRUCTION: In each case, TICK the appropriate box(es) and/or COMPLETE the statement(s).

		ITEM	SCORING	VARIABLE
A.	SEX:	Male ☐	2	**Sex**
		Female ☐	1	
B.	AGE:			**Age**

D. SCHOOL CERTIFICATE/GCE 'O' LEVEL QUALIFICATION IN MATHEMATICS:

Sat the examination: No ☐ 1

Teachers' Knowledge of mathematics

Yes ☐, If yes, *grade obtained*:

grades 1 to 3 ☐	5
grades 4 to 5 ☐	4
grades 7 or 8 ☐	3
grade 9. ☐	2

E. YEARS IN FULL-TIME TEACHING AFTER TRAINING:

	Experience
> 20 years	1
6-20 years	2
< 20 years	3

F. CLASS YOU TAUGHT - 1992/93 ACADEMIC YEAR **Level of teacher's class**

Lower Primary	1
Upper Primary	2

G. NUMBER OF PUPILS IN YOUR CLASS:

boys: .... girls: ....

total: **Class size**

< 20	1
20-35	2
36-50	3
> 50	4

COVERAGE IN PRIMARY MATHEMATICS TEACHING

Consider HOW MUCH TRAINING you have done on each of the following topics throughout the 1991/92
academic year and tick (□) :

(i) 'A GOOD DEAL OF TEACHING' If you taught the topic for more than 2 weeks;

(ii) 'SOME TEACHING' If you taught the topic for not more than 2 weeks;

(iii) 'NO TEACHING' If the topic was not taught at all; and

(iv) 'NOT INCLUDED' If the topic is not in the syllabus/textbook for your class.

		A Good deal of teaching	***Some of teaching***	***Virtually no teaching***
1.	Sets	2	1	0
2.	Number and Numerals	2	1	0
3.	Measurement of Length	2	1	0
4.	Measurement of mass (or weight)	2	1	0
5.	Measurement of Area	2	1	0
6.	Measurement of capacity	2	1	0
7.	Measurement of volume	2	1	0
8.	Measurement of time	2	1	0
9.	Arithmetic Operations	2	1	0
10.	Plane geometric figures	2	1	0
11.	Solids and 3-D shapes	2	1	0
12.	The number plane and graphs	2	1	0
13.	Graphs - pictograms, bar and pie	2	1	0
14.	Measurement of angles	2	1	0
15.	Movement geometry	2	1	0
16.	Averages	2	1	0
17.	Integers	2	1	0
18.	Fraction	2	1	0
19.	Operation on fractions	2	1	0
20.	Rational	2	1	0
21.	Percentages	2	1	0
22.	Ratio and proportion	2	1	0
23.	Simple interest	2	1	0
24.	Money, profit and Loss	2	1	0
25.	Chance	2	1	0

The Computer in the Mathematics Classroom: The Tool, The Tutor And the Tutee

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Abstract
Computers in the educational environment is not a new concept. Some schools in Zimbabwe have established computer laboratories in their schools, however, these computers are being used for computer literacy courses only and not for teaching purposes. This paper seeks to enlighten other educational practitioners that there is more that a computer can do for a teacher in the classroom. Robert Taylor's three modes of computer applications in the classroom (the tool, tutor, tutee) are discussed here.

Introduction

Computers appear to be revolutionising every aspect of our lives, for example the stores we shop, the cars we drive and even the games we play are being altered by computers. Computers are also found in the educational institutions, including schools, teacher training colleges and universities. However, these machines are rarely used in the classroom for teaching purposes. Generally, use of computer technology for teaching is not a new concept, but there is no other machine that has as many applications in the educational setting as the computer. Because of its power and outstanding software, it has the potential of becoming an important teaching aid in the classroom.

Literature Review

Research has shown that at the moment in Zimbabwe, most of the few teaching institutions that have computers and are offering computer courses have acquired these computers for computer literacy and computer studies, but not for teaching purposes.

Students are only taught word-processing, spreadsheets, databases etc. Research in other countries such as South Africa (Naidoo, 1999), the USA

(Clements and Battista, 1986), Malaysia (Gharzali M. et al 1997; Valero, 1997), and Greece (Olive, 1997) has shown that using computers when teaching stimulates learning is good for concept development, concept formation and concept reinforcement. It is also thought provoking, encourages group work and also allows students to manipulate and discover (things) on their own. Using a computer also has some positive effects on the teachers and their teaching approaches. It was noted that a teacher's teaching approach changes so as to accommodate the technology, and also teachers alter their values in the mathematics curriculum, (Olive, 1997). Pieper (1995) found out that thinking about how one can incorporate computer use into the curriculum causes teachers to continually reconsider what is being taught, how it is taught and even why certain topics are being taught.

Some Shortcomings of Our Position about Computer Use

There are some shortcomings which hinder the introduction of computers into the classroom (Gharzali M. Ismail Z.H. 1996) these include:

- Very few computers are available in schools. Those computers that exist are either obsolete or are being used for administrative purposes.
- Most teachers were trained without significant experience in computers.
- There is lack of appropriate courseware/software. The software that is available is not tied to the ongoing flow and changes of the curriculum.
- Use of computers in the classroom is simply not part of the culture and the society in general.

Despite these shortcomings we base the following discussion on the assumption that technological developments are not static but are improving and proving to be better with each passing day, so there is need to move with the trends and developments taking place world-wide.

The Three Categories

To facilitate the discussion of how computers can be used in schools and because as educators we do like to classify 'the inhabitants of our world', (Coburn, 1992) in (Kaput, 1992), the educational uses of computers are classified into three categories according to Robert Taylor's (1980) model.

- the computer as a tool
- the computer as a tutor
- the computer as a tutee.

The Computer as a Tool

In the computer tools category, we have the general purposes tools, special purpose tools, educational computer simulations, and artificial intelligence as an educational tool.

The General Purpose Tools

The general purpose tools are those computer applications that perform common information processing tasks for end-users, such as word-processing, spreadsheets, databases management systems, programming languages and so on.

Besides being an educational tool, the computer can also be a 'tool-maker'. This means that with the help of general purpose programming languages like Qbasic, Turbo Pascal, C, and C++, one can create his/her own applications. The designer does not only have to possess the necessary processing skills but should be knowledgeable in the area for which the tools are to be designed.

A computer is also useful for a teacher because of it's strong storage capabilities. The emergence of the dynamic versus static media concept has contributed to some major changes in the educational system. In static media, the states and forms of objects being denoted do not change over time but in dynamic media they do change. Examples of static media are paper and pencil and that of dynamic media are computer based storage devices. The major advantage of the dynamic over the static is that of interactivity between the computer and the user, that is the user can enter input and get feedback from the system.

Special Purpose Tools

Special purpose tools are those applications that are designed to support specific tasks of end-users. Examples in this category include business applications like the stock market, inventory management, educational computer simulations, and video programs in education. Available, as well are the 'narrowly-purposed' educationally oriented languages which are used to create tutorials, simulations etc.

Educational Computer Simulations

Computer simulations are programs which help a computer imitate real life situations. These programs can be used in a classroom as an educational tool. Olds et al (1980) destined two types of computer simulations. The first type is executed in parallel with the physical system that one is modelling. This enables the end-user (student/teacher) to compare directly the model with the system that is being modelled. For example when studying the motions of a pendulum. The second type of simulation can be employed when spatial or temporal scales prohibit the direct checking of the simulation with what one is modelling. For example, modelling of fractals in differential equations.

Artificial Intelligence in the Education System

Applications in business and society are being increasingly affected by developments in the field of artificial intelligence. Research and development efforts are being invested in the designing of artificial intelligence based tutors. Artificial intelligence can support the teacher by

providing help in the construction of materials and problems to be used by students. Most of the applications being designed nowadays have an element of intelligence.

The Computer as a Tutor

In a role of the tutor, the computer controlled by specially prepared software instructs the student in some skill or knowledge, usually interacting with the student according to the student's responses to prepared questions. In this category we have drill and practice, tutorials, and instructional games. We look at these separately.

Drill and Practice

This is the repetitive sequence of question - answer - feedback. Drill carries on until mastery of techniques and the basic pedagogy of drill and practices is limited to repetitive drill. If the answer is right, the computer presents the next problem. If the answer is wrong, the computer directs the student to try again. If the student types in a wrong answer repeatedly, the computer may instruct the student to seek help from the teacher or textbooks. If it is a sophisticated drill and practice and when a student misses a particular type of a problem repeatedly, the computer may provide a brief explanation of how to do problems of that sort.

Example

Computer Questions	**Students Response**
8 x 3	24
Right 6 x 6	36
Very Good 9 x 6	56
No Try Again 9 x 6	54
Good 7 x 8	42
No Try Again 7 x 8	58

No! You seem to be having trouble with these problems, ask your teacher for some help or read Chapter 3 of your text book.

Tutorial

In the tutorial mode, the computer instructs the students in some area of knowledge in more or less the same way a teacher would in a one-to-one situation. (There are crucial differences of course, a computer is not human.).

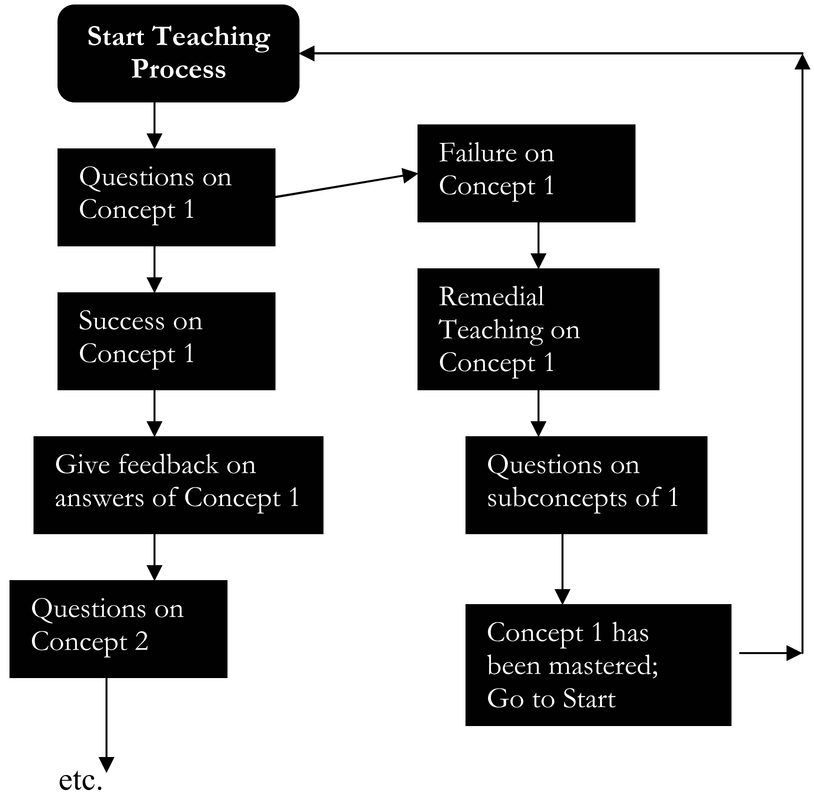

Figure 1 A Simple tutorial Model

The computer presents information about which it then asks a series of questions. The student types in a response that the tutorial program anticipates. Depending upon the nature of the response, the computer provides more information and asks further questions. In tutorial programs the programmer has to anticipate most of the potential responses that the students might make in order to create a meaningful dialogue. Tutorial enthusiasts note that with a tutorial the student gets a one-to-one student-teacher ratio, the students can proceed at their own rate and get an opportunity to respond to every "teacher query".

Figure 1 gives a simple tutorial model and illustrates the interventions of the computer, for remedial purposes.

Instructional Games

Instructional games are those computer games which have instructional goals. These are run by a clear set of rules and usually have a winner at the end. The games might involve.

Content games

These involve the teaching of some particular subject matter, for example, when the computer presents graphs of linear and quadratic functions and the student is to guess/deduce the function and get some points for a correct answer.

Process games:

These encourage processes in thinking (logically), reading, writing, counting etc, for example, the popular game 'Minesweeper' encourages thinking logically and counting.

It has to be taken into consideration that games should be used cautiously, as they tend to be addictive. It also has to be pointed out here that the tutor programs are written by human beings, these should be experts in the content area and should also understand the learning needs of students. Therefore a poorly written tutor program will be inefficient.

The Computer as Tutee

In the role as a tutee, the computer is programmed by the student, using one of the various programming languages, to do something that the student wishes done, e.g. writing a program that draws a graph of a quadratic function $f(x) = ax^2 + bx + c$ or a program that generates a sequence of numbers that satisfy a general formula $\frac{1}{n}$ with n increasing and hence determining the limit of a sequence as n approaches infinity.

One objective for the (Tutee Mode), student programming is based on the presumed general cognitive skills the student learns as a result of appropriate kinds of programming, such skills as, planning skills and problem breakdown skills.

Conclusion

There is no doubt that the computers can play a pivotal role in the achievement of educational objectives. The problem is the school structure when being developed never anticipated the implementation of new technology.

The school just like any other system has an environment (parents, society, administrators, etc) upon which it depends for existence. So, if new technology is to be implemented the school together with the environment need to decide how computer can help achieve the educational objectives.

But, for now, what is the way forward?

1. Student teachers should have computer use as a significant part of their teacher-preparation process. It has been noted that students cannot appreciate the full potential of computers unless they can see how it can be used as a tool.

2. For now the classroom practitioners need to fine-tune and then make use of the existing general purpose tools. Facilities offered by the word processing and spreadsheet programs can be effectively

used to reinforce concepts. For example, Fuglestad (1996) used spreadsheets to teach decimal numbers to 10-14 years olds.

1. To introduce computer technology into the classroom there is need for the redefining of educational objectives. Investigations need to be carried out to find out where the computer is appropriate in the teaching/learning process.

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The Appraisal of Mathematics Teachers in Ghana

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Abstract

This study examined the nature and existing methods of teacher appraisal in Ghana. 441 secondary mathematics teachers participated, of whom 193 teach the subject at the junior secondary level and 248 teach it at the senior secondary level. In addition, 44 Ghana Education Service Officials and 6 Heads of secondary schools who appraise mathematics teachers were sampled. Methods used included questionnaires, interviews and observation of appraisers at work. Chi-squareχ^2 and discriminant analysis statistics were used. Highly significant relationships were found between mathematics teachers' perceived professional support and appraisal experience, mathematics teaching experience and professional status at the senior secondary level; and between perceived support and appraisal experience at the junior secondary level. The results indicated inefficiencies in the appraisal system employed by the Ghana Education Service (GES) in supporting mathematics teachers to improve their work.

Introduction

Teachers constitute the most important (and perhaps the most expensive) resource in education, therefore there is no gainsaying that any educational system is as good as the teachers in it. It follows that the main way of improving the quality of learning that takes place in any educational system is to improve the quality of teaching in that system. One way of improving the quality of teaching is by providing teachers with the opportunity to develop professionally through the process of appraisal. This paper describes a study which aimed at assessing the potential of the appraisal system in the Ghana Educational Service (GES) to help mathematics teachers improve their work.

Teacher appraisal may be defined as the attempt by self and/or others to analyse and assess a range of professional knowledge, skills and attitudes which are relevant to the performance of a teacher's role within an institution or agency (Anderson, et al, 1987). Teacher appraisal can be both retrospective and prospective looking back at what has or has not been achieved, taking stock of the present and then planning some pathways which will help the individual teacher's professional development as well as her/his professional 'accountability'.

Used in the above context, teacher appraisal becomes synonymous with teacher evaluation, which also involves stock-taking and recommendations for improvement. In this paper, the two words (i.e. appraisal and evaluation) are used interchangeably and they mean almost the same thing.

The importance of school mathematics in the development of science and technology has been stressed by many governments in both 'developed' and 'developing' countries. It is therefore hardly surprising that mathematics arguably determines every child's social destination. In Ghana for example, not only is mathematics a compulsory subject at both the basic education and the senior secondary levels, a GCE "O" level credit (or its equivalence) in mathematics is a prerequisite for admission to tertiary institutions in the country. Surely, if every child is to participate "fully" in mathematics education in order to gain a fair chance of participating in further education (which is undoubtedly the key to gaining 'secure' employment in Ghana), then it is imperative that the teaching of the subject, particularly at the basic education and senior secondary levels, is continually improved.. Furthermore, considering that less than 50% percent of pupils from the junior secondary level gain admission to the senior secondary level (National Report, 1990), for the majority of Ghanaian children, the school mathematics that they are to be exposed to, should be of a quality that will adequately prepare them for adult life. Hence the need to provide mathematics teachers as well as teachers of other subjects with the opportunity to develop professionally through the process of appraisal. Yet the literature on teacher evaluation in Ghana (e.g. Bame, 1991) suggests that the appraisal process rarely does improve teaching quality.

It is however fair to point out that as part of the ongoing education reform, changes have been made in the appraisal system to enhance its ability to help teachers improve their work (Gokah, 1993). According to Gokah (op.cit), the changes are designed to "strengthen the management and supervision of basic education schools at the district and circuit levels" (p.3). These changes include the selection of Circuit Supervisors with higher qualifications and experience to be in charge of supervision of schools at the basic education level. At the senior secondary level too, the selection of supervisors has been streamlined to "ensure that the supervisors have adequate expertise in the teaching (and supervision of teachers) of the various subjects in the senior secondary school programme" (ibid.). As mentioned above, the study described in this paper looked at how well the appraisal system was in fact "working" after the above changes. It concentrated on the appraisal of mathematics teachers in Ghanaian secondary schools where mathematics is found most difficult both to teach and to learn (Boakye and Oxenham, 1982) and where others have done very little research. It sought to examine the validity of the teacher appraisal system and to identify some of the factors that are relevant to Ghanaian secondary mathematics teachers' perceptions of the potential of the appraisal system to help them improve their teaching of mathematics.

The Problem

Literature on teacher evaluation in Ghana (e.g. Bame, 1991, Gokah, 1993) suggests that a single system of teacher appraisal is used for both of the two most frequently cited primary purposes of personal appraisal, namely accountability and professional growth. The accountability (or summative) dimension reflects the need to determine whether a professional is competent in order to ensure that services delivered are safe and effective (Stiggins & Duke, 1988) whereas the professional growth (or formative) dimension reflects the need for development of the individual (Wragg et al, 1996).

Writers like Nuttal (1986) have argued that summative and formative purposes of appraisal can co-exist within the same scheme. Fullan (1991) has also noted that "combining individual and institutional development has its tensions, but the message ..... should be abundantly clear. You cannot have one without the other "(p.349). Yet McGreal (1988) argued that multiple purposes of evaluation can be successfully met with a single evaluation system only when the system is viewed as one component of a larger mission: that of furthering the goals of the organisation. If the dynamic relationship between the individual and the organisation is healthy, then what is good for the organisation must also be good for the individual and vice-versa. Indeed, Getzel and Guba (1957) in their classical model of social behaviour and the administrative processes described this dynamic relationship as one that fuses the prevailing interests of the institution with those of the individual. Such an orientation enhances the ability of both the individual and the institution to achieve desired goals and consequently encourages a satisfying state of affairs within the organisation and among its respective employees (Little, 1993; March & Simons, 1993).

If teacher appraisal is to provide a meaningful solution to the problem of helping teachers to improve on their work, then it is imperative that Ghanaian teachers see the Ghana Education Service in the light described above. This is why the concept of perceived organisational support is central to the present study. It must be emphasised further that in any system of appraisal, even if a single purpose is identified, those involved may see the purpose differently - senior management, for example, may see it in terms of their need to 'manage' staff whatever the purpose of appraisal is, whilst junior staff in their hierarchies may see it more in terms of their own personal development. These differences may be exacerbated when a single system is use for the dual purposes (of appraisal) as the literature suggests in the case of Ghana.

In such circumstances, and in view of the limited resources available to the Ghana Education Service, it is important to identify which teacher characteristics (and other variables) are significantly related to teachers' perceptions of the appraisal process. Hence the importance of considering teachers' perceived validity of the teacher appraisal system in Ghana. The question then is: how do the different categories of mathematics teachers perceive the performance appraisal system in the Ghana Education Service.

Hypotheses

A number of hypotheses were formulated using the relevant teacher characteristics to investigate the perceptions of different categories of teachers of the teacher appraisal system in Ghana. The hypotheses that were tested in the present study are as follows:

1. At both the junior and senior secondary levels, mathematics teachers who have been appraised will be more positive about the potential of teacher appraisal in Ghana to help them improve their teaching of mathematics than those who have not been appraised.
2. At both junior and senior secondary levels, more experienced mathematics teachers will be more positive about the potential of teacher appraisal in Ghana to help them improve their teaching of mathematics than less experienced ones.
3. At both junior and senior secondary levels, professional mathematics teachers will be more positive about the potential of teacher appraisal in Ghana to help them improve their teaching of mathematics than will non-professional mathematics teachers.
4. At both junior and senior secondary levels, female mathematics teachers will view the potential of teacher appraisal in Ghana to help them improve their teaching of mathematics differently from mathematics teachers.

Population

The target population for the study consisted of mathematics teachers in mid-southern Ghana - comprising the Ashanti, Central, Eastern and Greater Accra regions of Ghana. However, due to some practical difficulties, the study was limited to full-time secondary mathematics teachers in publicly operated secondary schools, referred to in this paper as "government (secondary) schools".

Sample

The sampling frame for the study consisted of the relevant secondary schools in the selected regions. This was done in spite of the fact that secondary mathematics teacher were the units of analysis of the study. In other words, mathematics teachers were sampled by schools. This design was preferred to simple random sampling of individual secondary mathematics teachers not only because it was to ensure that mathematics teachers in the selected regions were adequately represented, but it avoided the problem of the huge transportation and other costs involved in tracing teachers selected through simple random sampling. Also, as Stuart (1984) rightly points out, using simple random sampling in such circumstances could lead to high incidence of non-response and increase biases resulting from the latter.

However, in an attempt to preserve the random principle on which statistical inferences depend, while at the same time allowing for a design

that would ensure adequate representation of teachers in the sample regions, the study used a stratified cluster sampling method to select participants. Stratification was done by region and type of school (i.e. whether junior or senior secondary).

At the senior secondary school level, mathematics teachers were sampled by schools selected at random from a list of schools in each region. 15 schools were selected in each of the Ashanti and Eastern regions whereas 10 schools each were selected from the central and Greater Accra regions. The number of schools selected in each region reflected the number of schools in the region. In all, 50 senior secondary schools were involved in the study, and all the mathematics teachers in these schools were sampled.

Unlike the senior secondary schools, junior secondary schools in Ghana are scattered throughout the whole country. Nearly every single town or village with a primary school has a junior secondary school. Because of this, the method of sampling mathematics teachers by schools (selected at random from a list of schools in each region) proved extremely difficult and almost impossible to use. Two districts were therefore selected at random from each of the 4 regions. In each district, 4 circuits were selected at random and all the mathematics teachers in the selected circuits were sampled. In all 129 junior secondary schools participated in the study.

The sample sizes for the junior and senior secondary were 193 (with 12 absentees) and 248 (with 46 absentees) respectively. Thus the study involved 441 junior secondary and senior secondary mathematics teachers. With regard to the appraisers, 44 GES officials (and 6 heads of senior secondary schools) who appraise mathematics teachers took part in the study. The constitution of the appraisers who were sampled is as follows: the circuit supervisors of the 8 selected circuits in each region were sampled. In addition, 2 inspectors were sampled from each of the four regions and all the inspectors at the headquarters of the Inspectorate Division of the GES were sampled. In all, out of the 50 supervisors/appraisers sampled, 44 responded, giving an overall response rate of 88 percent. Attempts to recover the non returned questionnaires were not successful.

Instruments

Preparations towards the pilot as well as the main study involved a number of steps. Preparations began with the study of similar studies and the materials used in them. For example, in order to identify the appropriate items to include in both the mathematics teacher appraisal questionnaire (referred to in this paper as the *teacher questionnaire- see Appendix A)* and the appraiser questionnaire (see Appendix B), the researcher examined a number of existing instruments.

With regard to the teacher questionnaire, these were instruments which aimed at assessing teachers' attitude towards the teaching and learning of mathematics and those assessing their attitude towards teacher appraisal generally. As no study involving the appraisal of mathematics teachers had come to the researcher's notice, most of the items used in the study were

modifications of those used in mathematics education studies which were somewhat related to the present study (e.g. Kouba, 1994). Other items used were borrowed from instruments used in teacher appraisal studies generally. Specifically, some of the items on Ghanaian teachers' attitude towards Ghana Education Service officials' supervisory activities were either borrowed or adapted from the items used in the teacher motivation study described by Bame (1991). Those items regarding teachers' attitude towards mathematics teaching and learning were adapted from studies investigating mathematics teachers' attitude towards the teaching and learning of the subject (e.g. Raymond, 1993). Some of the items used in the appraiser questionnaire were similar to those used in the teacher questionnaire. Such items were derived from the same instruments as those on which the teacher questionnaire were based. Other items were derived from Ghanaian teachers' expressed opinions about the supervisory activities of GES officials in similar studies.

Preparations towards the interviewing exercise involved much the same steps undertaken to develop the two questionnaires. They involved the development of interview 'blue print' specifying the areas to be covered and the questions to be asked. As in the case of the questionnaires, the preparation began with the study of materials describing the process of interviewing (e.g. Anatasi, 1986; Oppenheim, 1990). These materials included manuals, descriptive articles and transcripts of interviews carried out using the "critical incident" technique (Hoyles, 1982). These initial exercises provided a sense of the form the interviews in the present study should take, the appropriate questions to ask and the probes and prompts to use.

Piloting and Administering the Instruments

The instruments prepared for the study were tested in a pilot study which was conducted from October to December 1998. Thus the purpose of the pilot was to gain insight into the relative strengths and weaknesses of the research instruments in order to make possible improvements prior to the main study. The sample for the pilot study consisted of 50 secondary mathematics teachers and 10 appraisers selected from two districts in the regions selected for the real study.

The main study was conducted from February 1999 to May 1999. The teacher questionnaires were administered personally by the author, after the latter had been granted permission by the directors of education in the districts (and regions) involved in the study. At the junior secondary level, circuit supervisors in some of the districts were directed by the district directors to inform all mathematics teachers in their circuits about the research and to arrange a meeting of all mathematics teachers at specified venues.

Results

Appraisal Experience

The first hypothesis tested was the one formulated to examine the

relationship between appraisal experience and perceived support. The prediction was that at both junior and senior secondary levels, mathematics teachers who had been appraised would be more positive about the potential of TAG to help them improve their teaching of mathematics than those who had not been appraised. At both levels, appraisal experience was significantly related to perceived support at the 1% alpha level.

At the junior secondary level, 113(76.4%) out of the 148 respondents who had been appraised were positive about TAG as compared to 24(53.3%) of the 45 who had not been appraised, χ^2 (1, N=193) = 7.7944, $p<.01$. At the senior secondary level, 64(41.3%) out of the 155 respondents who had been appraised were positive about TAG, while 62(66.7%) out of the 93 non-appraised respondents were negative about TAG, χ^2 (1, N=248) = 13.9778, $p<.01$.

Mathematics Teaching Experience

The second hypothesis tested in the present study concerned the relationship between experience in mathematics teaching and perceived support. It was predicted that teachers who had taught mathematics for longer periods would be positive about the potential of TAG to help them to improve their teaching of mathematics. At the junior secondary level 50 (73.5%) out of the 68 teachers who had taught mathematics for more than five years were positive about the potential of TAG to help them to improve their teaching of mathematics whilst 87 (69.6%) of the 125 teachers with five years or less experience in mathematics teaching viewed TAG positively. It may be noted that, on the face of it, the difference between "experienced" and "inexperienced" mathematics teachers in terms of perceived support was not statistically significant even at the 50% alpha level, χ^2 (1) = 0.1669, $P > 50$.

Gender

The fourth hypothesis tested in the study was about gender differences in perceived professional support. It predicted that at both junior and senior secondary levels, female mathematics teachers would view the potential of TAG to help them improve their teaching of mathematics differently from male mathematics teachers. The results obtained were apparently unsupportive of this hypothesis for, at both levels, no significant differences were found between males and females about their views about TAG. At the junior secondary level, 16 (67%) out of the 24 female mathematics teachers and 121 (71.6%) out of the 169 male mathematics teachers were positive about TAG. As mentioned above, the difference between female and male respondents with regard to their views about TAG was not significant, χ^2(1, N=193) = 0.2056, $P> 50$.

At the senior secondary level, the corresponding figures (indicating positiveness towards TAG) were 13(54.2%) out of the 24 females and 113(50.4%) out of the 224 male respondents. Here too, the difference between males and females in terms of their views about TAG was not significant, χ^2 (1, N=248) = 0.2056, $p>.50$.

Further Analysis

Readers may have noticed that in the chi-square analyses presented above, independent variable was used at a time. This means that the chi-square analyses provided no means of examining the combined 'effect' of the independent variables on the dependent variable. It also means that they provided no means of disentangling the web of correlations that appeared to exists between the independent variables in order to find the effect each of them had on the dependent variable 'on its own'. It therefore seemed necessary to re-examine the variables discussed above using procedures that would take into account not only the relationships between the various independent variables, but also those between a combination of the latter and the dependent variable. Thus, in an attempt to throw more light on the relationships between the main (dependent and independent) variables discussed above, as well as find out how the independent variables affect the dependent variable directly or indirectly, linear discriminant function analyses were done.

Each of the variables was examined to see how best it can, on its own, discriminate between the above groups of teachers on the basis of their scores on the dependent variable. Put differently, the discriminant power of each variable was calculated for each of the sets of data (i.e. junior secondary, senior secondary, and the combined sets). The discriminant power of each variable was arrived at by finding the percentage of "grouped" cases correctly classified by the variable on its own, using the "stepwise" procedure on the SPSS discriminant analysis programme. The table below gives the discriminant power of each of the variables of interest.

Table 1 Discriminant power of the main independent variables

Variable	Junior Secondary % classified correctly	Senior Secondary % classified correctly	Combined Data % classified correctly
Appraisal experience	70.98	61.69	-
Maths teaching experience	-	62.90	59.64
Professional status	-	66.13	66.44
Gender	-	-	-

The above table shows that, at the junior secondary level, appraisal experience could, on its on, correctly classify 71 percent of the respondents into two groups - positive and negative - in terms of their actual 'scores' on the dependent variable.

None of the remaining three variables namely, m*athematics teaching experience*, *gender* and *professional status* could, on its own, classify any of the respondents. In other words, they were too weakly related to the dependent variable to classify any of the respondents - an observation

which appears to confirm the results reported in the last section.

At the senior secondary level, and in much the same way, each of the three variables that correlated significantly with the dependent variable at that level (when chi-square values were used) could, on its own, assign respondents to the two groups with some degree of success. For the combined data, the variables, *mathematics teaching experience* and *professional status* were the only ones that qualified for analysis, with *professional status* emerging as the best single variable for correctly classifying 66 percent of all the 441 respondents.

As may be inferred from the above results, the linear discriminant function analysis confirmed the results obtained from the chi-square analysis.

Discussion

It is interesting to note that at both levels and in both analyses, gender was not significantly related to the dependent variable. This result and the lack of significant relationship between the dependent variable and both mathematics teaching and professional status at the junior secondary level need to be explained. Also to be explained is the fact that contrary to the prediction that at both junior and senior secondary levels, mathematics teachers who had been appraised would be more positive about the potential of TAG to help them improve their teaching of mathematics than those who had not been appraised, the relationship between the two variables were in different directions at the two levels. Whereas the relationship between appraisal experience and perceived support was in the predicted direction at the junior secondary level, the direction of the relationship between the variables was reversed at the senior secondary level.

Explaining first the apparent difference between the groups in the direction of the relationship between the dependent variable and appraisal experience, one major reason why the results at the senior secondary level showed a deviation from the prediction is the type of appraisal experience the respondents get a the two levels. As mentioned above, 44 Ghana Education Service officials (GESOs) who appraised mathematics teachers at either the JSS level or SSS level took part in the study. Of these 29 were circuit supervisors who appraise mainly junior secondary mathematics teachers as well as teachers of other subjects. The remaining 15 appraisers were responsible for appraising teachers at the secondary level. Although at the latter level, emphasis is placed on subject specialisation and that where possible, GESOs are supposed to appraise teachers who teach the appraisers' specialist subjects, most of the officials who had appraised mathematics teachers were not mathematics specialists.

In fact, only 8(18.8%) of the appraisers who had appraised mathematics teachers were mathematics specialists. Of the 8, three appraised mathematics teachers at the junior secondary level and five appraised mathematics teachers at the senior secondary level. What is more, not all the non-mathematics specialists had been trained in the appraisal of

mathematics teaching. As many 15(41.6%) of the 36 non-specialists had not been trained. Eight of these were operating at the junior secondary level whereas seven of the untrained non-specialists operated at the senior secondary level. Thus of the 15 appraisers who appraised mathematics teachers at the senior secondary level, 7 (47.0%) were either non-specialists or not trained! The corresponding percentage at the junior secondary level was about 17%. Thus whereas 27 percent of the appraisers at the junior secondary level lacked the expertise in mathematics teaching or it's appraisal, as high as 47 percent lacked such expertise at the senior secondary level. As Ball (1988) points out, "knowledge of mathematics is obviously fundamental to being able to help someone else learn it" (p.12). Many of the appraisers at the senior secondary level were not in the position to help mathematics teachers improve their performance. In other words, the feedback most of the mathematics teachers especially those at the senior secondary level got from the appraisers could affect their perceptions of the appraisal system negatively. The suggestion is that mathematics teachers who doubt the expertise of their appraisers would not be satisfied with the appraisal feedback from such appraisers (Larson & Callan 1990; Raymond 1993).

It is worth reiterating that, apart from appraisal experience, the relationship between perceived support and each of the variables *mathematics teaching experience* and *professional status* was the reverse of the one predicted at the senior secondary level. At the junior secondary level, no significant relationship was found between the dependent variable and either of the two variables under discussion.

The leader-member exchange model describes the process by which members in an organisation evolve their roles through interactions with their supervisors. As a result of this process, quality of exchange ranging from low to high develops between the teacher and the supervisor. Early research examining the model indicated that a superior develops different quality exchange relationships with subordinates and these relationships are relatively stable over time (Dansereau et al., 1975; Graen & Cashman, 1975). Later studies (e.g. Kingstrom & Mainstone 1985) were focused on the relationship between exchange quality and supervisor and subordinate attitudes and behaviours. Results suggested that, in comparison with a low quality exchange relationship, a high quality exchange relationship is related to more supervisor support and guidance, higher subordinate satisfaction and performance, greater subordinate influence in decisions and lower subordinate turn over (Kingstrom and Mainstone, op. cit.)

The relationship between Ghanaian teachers, particularly the experienced ones, and their supervisors has been far from anything that can promote high quality exchange behaviour between the two groups. The rather depressing relationship that has, until recent 'changes' made in line with the new eductional reform programme, existed between teachers and their supervisors is well documented (Bame, 1991). It would appear that in spite of the changes that the reform is purported to have brought in the

supervision of teaching by the reform, the relationship between teachers and their supervisors does not seem to have changed for the better.

Thus following Graen & Cashman's (1975) observation about the relative stability of superior - sub-ordinate relationships over time, it is reasonable to expect more experienced teachers especially at the senior secondary level (most of whom witnessed for longer periods the hostile attitudes of the supervisors before the introduction of the new reforms) to make "on-line" judgments in the negative direction about the supervisory activities of GES officials. This could be more so in the case of mathematics teachers, considering that most of the supervisors might not have the requisite knowledge in mathematics or its teaching to enable them offer any help to these teachers.

It may be recalled that the hypothesis concerning professional status stated that at both junior and senior secondary levels, professional mathematics teacher's will be more positive about the potential of TAG to help them improve their teaching of mathematics. At both levels, there was a deviation from the prediction. Whereas no significant relationship was found between professional status and perceived support at the junior secondary level, the predicted direction of the relationship between professional statuses and perceived support was reversed at the senior secondary level. Both results need to be explained.

Firstly, the difference between junior secondary and senior secondary mathematics teachers with regard to the relationship being examined may be due to the difference between the proportions of professionals at the two levels. Indeed the tiny proportion (11.4%) of professional respondents at the junior level makes any conclusion about the relationship between professional status and perceived support at the junior secondary level appears unsafe. The tentative conclusion therefore is that there was not sufficient data at the junior level to enable safe conclusions to be drawn notwithstanding any claim that the data were representative of the proportion of professional mathematics teachers at the two levels.

Secondly, considering that most of the appraisers at both junior and senior secondary levels were found to lack expertise in mathematics, it is no exaggeration to suggest that the difference between the two groups of teachers may be due to the possible differences in the levels of competence and self-concept in mathematics between the two groups. Indeed, Grouws (1992) has cited a number of studies (e.g. Byrne, 1984; Marsh, 1986) on individuals' self-concept in mathematics which findings suggest that the relationship between self-concept and achievement is consistently positive. If these findings are anything to go by, then teachers who have low achievement levels in mathematics and as a result poor self-concept in the subject, would be more likely to accept feedback from an external source than those with high self-concept in the subject. It is suggested that the professional teachers at the junior secondary level differ from their counterparts in the senior secondary schools in terms of self-concept in mathematics. This view was supported by the interviews conducted during the study. The following views expressed by two of the respondents (both of

whom were professionals and had taught mathematics for over 10 years) when asked to suggest how the appraisal process in Ghana could be improved illustrate the point made above.

The junior secondary mathematics teacher said:

> "I think the appraisals (I have had) have helped me. Now I can prepare my lesson notes very well. I can also teach better because now I give more exercises. I can see the student are picking up …"

The senior secondary mathematics teacher on the other hand commented:

> "…. First, they (i.e. the GES) must replace most of the officials who do appraisals… These people cannot help any classroom teacher. We need very qualified mathematics teachers, those with good mathematics education background to be in the office so that they can go round and help mathematics teachers at both the JSS and the SSS levels. Mathematics is not like the other subjects where students can study by reading prescribed textbooks. …. The subject as you know it yourself is very abstract so students find it very difficult even when a teacher explains the concepts to them. So I think the officers must be well qualified mathematics teachers…." …

It may be noted that whereas the professional "junior" mathematics teacher expressed acceptance of the external source of appraisal feedback as well as the feedback itself, his counterpart at the senior level not only rejected the appraisal feedback given by GESOs, but called for the replacement of most officers who appraise mathematics teachers. One important implication of the above findings is that when it comes time in an appraisal process to provide feedback, the recipient's perceptions of the sources qualifications to provide adequate feedback become critical to their intention to accept (and use) the feedback.

The fourth hypothesis tested was about gender difference in perceived professional support. It predicted that at both junior and senior secondary levels, female mathematics teachers would view the potential of TAG to help them improve their teaching of mathematics differently from male mathematics teachers. The results obtained were apparently unsupportive of this hypothesis, for at both levels, no significant differences were found between males and females about their views about.

Inasmuch as one would wish to explain the above "deviation" from the hypothesis, it is important to point out the difficulties involved in explaining the null results involving gender in the present study, especially considering the small number of female mathematics teachers who took part in the study. At either levels, 24 females took part in the study. This figure represents 12.4% and 9.7% at the junior and senior secondary levels respectively. In any case, at both levels, nearly equal proportions of males and females were positive or negative about the potential of TAG. This observation was supported by the fact that of the 5 female mathematics teachers interviewed (2 from the junior secondary level and 3 from the senior secondary level) 2(40%) were positive. about TAG. This proportion was almost the same as that of their male counterparts who were positive

about TAG. Specifically, 13(40.6%) out of the 32 male mathematics teachers who were interviewed were positive about the potential of TAG. Consequently, no further discussion of the data on gender can be justified. Nevertheless, the data may be the starting point of further research, looking, for example, at gender differences in performance appraisal ratings.

Other Findings

In addition to the findings resulting from the testing of the hypotheses, the study made other findings through the interview and observation data. For example, the study found that in line with the Ministry of Education's stand on appraisal, the system was, at the time of the study, being used for both staff development and the assessment of performance for promotion and other related purposes. In fact, not only was the appraisal system used for both accountability and professional development purposes, the same set of officers were used for both purposes! The lack of expertise among these officers clearly invalidated the appraisal system (Brown & Borko, 1992).

Besides, the dual use of an appraisal system often creates confusion as teachers are most of the time not aware of what purpose they are being appraised for. This confusion appears to confirm the fears of writers like Powney (1991) who hold the view that no appraisal system can serve both purposes. Bame (1991), for example comments on the dilemma the dual role poses in the Ghanaian educational setting:

> We noted that (the) majority of both the teachers and headteachers acknowledge the usefulness of some aspects of the supervision carried out by officials, in that it helped teachers to improve their teaching. But at the same time, they indicated that … the officials always tried to find fault with … teacher's work.(Bame, op. cit pp. 114 - 115).

The study also found in confirmation of Gokah's (1993) observation that only the managerial appraisal method was being used in the appraisal of mathematics teachers in Ghana. Classroom observation was found to be the main instrument for the collection of data for teachers' work for both formative and summative appraisals, particularly at the junior secondary level. It was found that classroom observation when it was used to collect data about teachers work for either purpose was used once or twice, not more. It is worth pointing out that the scanty samples of teachers work used in summative evaluations weakened the validity of classroom observations in the present study.

The only other instrument used to appraises mathematics teachers for summative purposes was the promotion interview. Here too, the study concluded that the nature of questions mathematics teachers were asked at such interviews invalidated the interviews. This is because the interviewers did not ask enough questions about teachers' classroom practice. Far too many of the questions were on issues that bore no relevance to mathematics teaching. Asked why general knowledge questions dominated the interviews, an officer who served on one of the interview panels said:

> "… We consider the teacher's work generally…. I mean classroom work and other work outside the classroom … you know at this level, the teacher is not supposed to know not only his (sic) subject area, but also everything about the GES and GNAT and current affairs. Therefore, we ask questions on all these areas … I said he has to know more than (the classroom work). He has to be an all round teacher … You see at this level we expect teachers to know a lot about administrative work because they can become assistant heads or senior housemasters and they should be able to solve problems … They should be able to solve problems in the classroom, problems in the school, problems in the home and so on. In fact, we are looking for an all round teacher. He shouldn't only concentrate on his subject area … One thing is that most of the people who fail the interview concentrate only on their subject areas and that's why they fail. Even some teachers with master's degrees fail because they think the other areas like current affairs and issues concerning the GES are not important. They say why should I worry about problems in the GES when I have my classroom work to do…. But you see things don't work like that in the GES. We want teachers who can solve problems…. Well, most of these teachers when they fail at the first sitting, they go back and study the other things well so that they are able to pass the second time round…."

When asked whether a mathematics teacher's knowledge of the subject matter and how they do their work as a mathematics teacher alone cannot help them to pass the promotion interview, the above officer said: "No. These two things are not enough:". Although he admitted that the way the interviews are conducted is likely to have negative impact on (mathematics) teaching, he still maintained that it was important that teachers excelled in "all areas". He argued:

> "… Yes, we know that certain categories of teachers are frustrated by the way the interviews are done, especially those teachers who don't consider areas other than their own areas important. Most of these teachers complain about the interview. Such frustrations can affect the performance of these teachers but there isn't much we can do about it… That is the GES policy … that all teachers who get promoted are well versed in other areas outside their own areas too. We want an all-round teacher. There is also another category - the non-professionals. According to a GES policy, non-professionals cannot go beyond the grade of senior superintendent. Such teachers are also frustrated by the system but I think they have themselves to blame … We want professionals in the education service so those who enter the service must either be professionals from Cape Coast (University) or take the opportunities that are being provided by the GES to turn themselves into professionals. For example, there is this diploma in education sandwich course (run by the University of Cape Coast). They take this course and within 2 years, they have become professionals. Many teachers don't take the opportunity, yet they complain about promotions…"

The officer rightly argued that although academic qualifications are important in the teaching profession, they are not enough to make one a good teacher and since the GES was committed to rewarding good teachers, other factors had to be taken into account. Even so, not asking a mathematics teacher or indeed any teacher enough questions about their classroom practice leaves one in doubt as to what the purpose of the promotion interview is.

Conclusion

The findings of the present study lead to the conclusion that the teacher appraisal system in the Ghana Education Service is far from valid. It must be emphasised, however, that knowing (rightly) that the system of teacher appraisal in Ghana is not valid, and improving one's teaching are two different things. Professional mathematics teachers may be aware of the lack of mathematical expertise among their appraisers but this knowledge cannot on its own help them to improve their work. In fact, such knowledge can even lead to complacency! It appears the main way of helping teachers to improve their work through the teacher appraisal system in Ghana is, in view of the findings of the present study, to make changes to the present system of appraisal of teachers in Ghanaian schools generally and that of the appraisal of mathematics teachers in Ghanaian secondary schools in particular. Indeed, both Nyoagbe (1993) and Bame (1991) recommended that there should be restructuring of the supervisory relationship between officials and teachers. They both urged officials to show educational leadership by suggesting new ideas to teachers and by practical demonstrations which will help the teachers discover alternative means of improving their work. This view was shared by nearly all the mathematics teachers who took part in the study, especially those at the senior secondary level. They all expressed the need for professional support through formative appraisal processes conducted by competent officials who would be capable of raising their confidence in the teaching of the subject.

Thus, in addition to Nyoagbe's (1993) recommendation that "the GES should appoint a good corps of supervisors to infuse professional consciousness in teachers and guide them to improve [their] performance" (p. 15), teachers must perceive the supervisory activities of present and future officials in a positive light.

As far as the appraisal of mathematics teaching is concerned, these officials should be conversant with the teaching of mathematics at the pre-tertiary level of the education system. Admittedly, it would be extremely expensive to appoint supervisors subject by subject, yet if the emphasis the government is putting on mathematics, science and technology is to translate into real gains in these fields, then there is the need to train professionals who would help teachers in these areas. Such professionals when appointed should go through a period of intensive training during which time they would be exposed to different uses of appraisal and how they can be applied to suit local conditions. In addition to the pre-service training, they must be given the opportunity to attend international courses and conferences on appraisal.

Another important observation is that, the findings of the present study call for the reintroduction of mathematics and science *organisers* at the district offices. These organisers were redeployed as part of the reform programme. Many of them are now in charge of the Basic Education Certificate of Education examinations, serving as links between the district offices and the West African Examinations Council. This redeployment has clearly led

to waste of vital "resources"! These specialist officers ought to be responsible for the professional development of junior and senior secondary mathematics and science teachers whereas the present supervisors would concentrate on the general running of the schools by heads and deal with matters relating to allocation and uses of educational facilities. This means that the organisers must be very well qualified and experienced teachers some of whom may even be drawn from the universities. Should the circuit supervisors need information about mathematics teachers' professional needs, they should collect such information from the mathematics organisers, who will only give such information with the teachers' consent.

With regard to appraisal for promotion and other summative purposes, the GES should train officers who would be able to 'assess' teachers' performance accurately if such assessment would be needed for such summative purposes. Most importantly, the promotion interviews should reflect the type of work teachers do in their classrooms as such a move could encourage teachers to learn more about what is expected of them as mathematics teachers. It appears that one of the reasons why appraisers at promotion interviews do not attempt to ask mathematics teachers any questions about the subject is their lack of confidence in the subject. This means that if the promotion interview is to reflect mathematics teachers' classroom work, then those who interview them must be mathematics specialists who would understand the various problems facing mathematics teachers in the secondary schools.

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APPENDIX A
Mathematics Teacher Appraisal Questionnaire

The questionnaire (which you are being requested to kindly complete) forms part of a teacher appraisal study, with particular reference to the teaching of mathematics. The study will enable the researcher learn about some of the ways in which the teaching and learning of mathematics in this country can be improved. To ensure complete anonymity, please do ***not*** write your name on your questionnaire.

SECTION 1

1. Please state your sex .... M/F

2. Do you teach mathematics only? . Yes/No
   If you do not teach mathematics only, what other subject(s) do you teach?
   ....
......

....

3. Please state the level (and form) at which you teach mathematics
   i) level(s) (e.g. JSS, SSS, etc) ....
   ii) form(s) ....

4. For how long have you been in the teaching field? Please circle one range only.
   a) less than 5 years b) 5 - 10 years c) over ten years

5. For how long have you been teaching mathematics? Please circle one range only.
   a) less than 5 years b) 5 - 10 years c) over ten years

6. Please indicate the type of certificate(s) you have. You may tick more `than one.
   a) .... Teacher's certificate A
   b) .... Specialist Mathematics
   c) .... Diploma in Mathematics
   d) .... BSc (Ed)/B.Ed Mathematics
   e) .... Other, please specify

7. Have you ever been appraised as a mathematics teacher? .... Yes/No

   If yes, please state the last time you were appraised and for what purpose

   Last appraiser (e.g. headteacher, circuit supervisor, etc.)
   ....
   Purpose (e.g. promotion, professional development, etc.)
   ....

In this section, we ask you questions about your teaching of mathematics and what you can do to improve it.

8. Please state 3 ways in which you can improve your teaching of mathematics
   1st. ……………………………………………………………………………
   ……………………………………………………………………………
   2nd ……………………………………………………………………………
   ……………………………………………………………………………
   3rd ……………………………………………………………………………
   ……………………………………………………………………………

9. Can the way teacher appraisal is done (presently) in this country help you to do the first (1st) thing you have stated in item of above? Yes/No
   ……………………………………………………………………………………

11. Can the way teacher appraisal is done (presently) in this country help you to do the third (3rd) thing you have stated in item 8 above? …………………………

    If no, please state how teacher appraisal *can be improved* to help you to do the third (3rd) thing you have stated in item 8 above.

12. Please state the position of who you think is the most appropriate person to appraise you AND for what purpose(s).
    i) the position of your preferred appraiser
    ……………………………………
    ii) the purpose(s) is/are ..
    ……………………………………………………………………
    ……………………………………………………………………

Thank you very much for your help.

APPENDIX B
APPRAISER QUESTIONNAIRE

The questionnaire (which you are being requested to kindly complete) forms part of a teacher appraisal study, with particular reference to the teaching of mathematics. The study will enable the researcher learn about some of the ways in which the teaching and learning of mathematics in this country can be improved. To ensure complete anonymity, please do NOT write your name on your questionnaire.

1. Please state your sex .... M/F
2. Do you appraise mathematics teachers only? .... Yes/No

   If you do not appraise mathematics teachers only, what other teachers do you appraise?
   ....
   ....
   ....

3. Please state the level (and) form at which you appraise mathematics teachers
   (i) Level(s) (e.g. JSS, SSS, etc) …………………
   ii) form(s) …………….

4. For how long have you been in the teaching field ? Please circle one range only.
   a) less than 5 years b) 5 - 10 years c) over 10 years

5. For how long have you been appraising mathematics teachers? Please circle one range only one.
   a) less than 5 years b) 5 - 10 years c) over ten years

6. Please indicate the type of certificate(s) you have. You may tick more than one.
   a) …………. Teacher's certificate A
   b) ………… Specialist Mathematics
   c) ………… Diploma in Mathematics
   d) ………… BSc (Ed)/B.Ed Mathematics
   e) ………… Other, please specify
   ……………………………….

7. Have you received any training in the appraisal of mathematics teaching?
....
Yes/No
If yes, please state:

i) did you find such training adequate .... Yes/No
ii) what did you like/dislike about the training?
....
....

8. How is the appraisal of mathematics teachers different from that of other teachers at the level(s) which you apprise teachers at?
....
....
....

9. After classroom observation of a mathematics lesson, how does the teacher get to know how he/she performed in the lesson?
....
....
....

10. How long does it take you to have a pretty good idea about a mathematics teacher's work to enable you to pass judgment on his/her performance?
....
....
....

Thank you very much for your help.

Graphing Calculator: A Way Forward

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Abstract

This paper highlights on how graphing calculators could be used not only as a teaching tool but also as a learning aid and the future of this machine in our match towards computer age.

Introduction

The recent times has seen a surge in the usage of graphing/programmable calculators among students at different levels on the education ladder. However the fullest potential of this machine with respect to its proper integration into the teaching and learning of Mathematics still remains untapped. More disturbing is also the fact that a very good number of the holders/users of these calculators cannot use them to the optimum.

Materials and Method

Using 'TI – 92 Plus' as a model graphing calculator, we demonstrate how problems in numerical methods and optimisation techniques could be solved. A comparison is made with a 486 PC in respect of computational time and accuracy.

Even though the various problems could have been solved on the home screen program codes was preferred for purposes of demonstration. This approach was adopted because it not only increases the computational accuracy and time, but also gives the user a feel of how to write his/her own programs for other problems. There is the other advantage of enhancing ones ability to write computer programs using basically the same logic.

Demonstration 1

As our first activity, we demonstrate how the graphing calculator could be used to find the numerical solution of a parabolic type of a partial differential equation (the equation of heat flow) using the method of Crank-Nicolson (see Kincaid (1994) and Jain (1991)).

***Outline o*f Method**

The Crank–Nicolson method finds the numerical solution at grid points in a mesh. Generally the method with the assumption that U(0,t) = U(1,t) = 0, t ≥ 0 is given by the formula

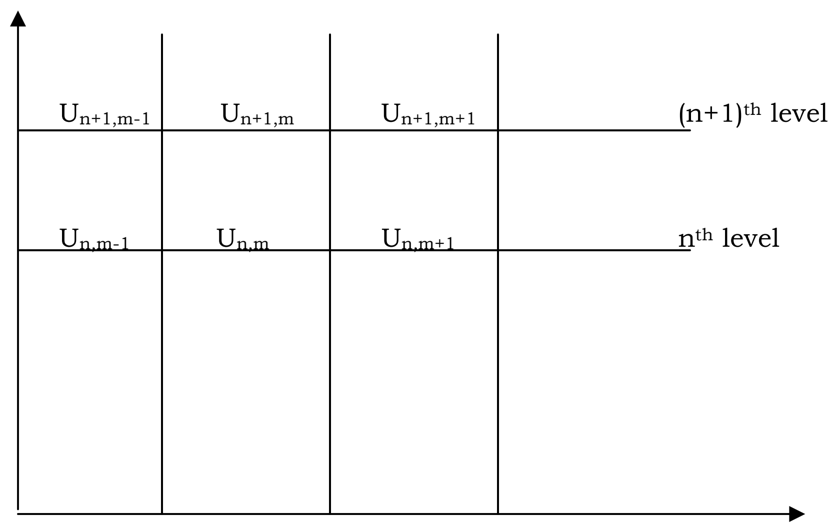
$$\Delta t U_m^{n+1} = \tfrac{r}{2}\delta_x^2\left(U_m^{n+1} + U_m^n\right)$$

or

$$-U_{m-1}^{n+1} + (2 + 2/r)U_m^{n+1} - U_{m+1}^{n+1} = U_{m-1}^n + (2/r - 2)U_m^n + U_{m+1}^n$$

where $\mathrm{n} = 0,1,2,\cdots,\mathrm{N}$ and $\mathrm{m} = 1,2,\cdots,\mathrm{M}$

The computational molecule of the Crank–Nicolson is shown below.



Program Code Used with the Graphing Calculator to Solve Heat Flow Equation with the Crank–Nicolson Method

Program code for the Crank–Nicolson method that could be coded into a TI-89, TI-92 and TI-92 plus graphing calculators to solve heat flow equation is presented below.

```
: nicolson()
: Prgm
: Local  i,t,m,n,h,k,xm,um,bt,n1
: ClrIO
: InputStr  "Enter function U(x,0)=?", fn
: Define f(x) = expr(fn)
: Input  "Enter number of levels", n1
: Input  "Stepsize in x – dxn, h?", h
: Input  "Stepsize in t–dxn, k?", k
```

```
: 1/h-1→n : 1→t
: k/h^2→r
: newMat(n,n)→mt : newMat(n,1)→bt
: seq(f(x),x,0,1,h)→xm
: dim(xm)→m
: For i,1,n
:  2+2/r→mt[i,i]
:  For j,1,n
:   If j=i+1
:    –1→mt[i,j]
:    If j=i-1
:    –1→mt[i,j]
:   EndFor
: EndFor
: ClrIO
: Pause mt
: Loop
:   For i,1,n
:    xm[i]+(2/r-2)*xm[i+1]+xm[i+2]→bt[i,1]
:   EndFor
:   simult(mt,bt)→um
:   ClrIO
:   Disp "SOLUTION AT LEVEL "&string(t)
:   Pause um
:   If t=n1
:   Exit
:   t+1→t
:   0→xm[1] : 0→xm[m]
:   For i,1,n
:    um[i,1]→xm[i+1]
:   EndFor
:  EndLoop
: EndPrgm
```

As an illustration, we use program code Nicolson written to solve the following partial differential equation:

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial x^2} \ , \ 0 \le x \le 1 \ , \ 0 \le t \le 1$$

$$u(x,0) = u(x,1) = x^2 - 1 \ , \ 0 \le x \le 1$$

$$u(0,t) = u(1,t) = 0 \ , \ 0 \le t \le 1$$

by use of the Crank–Nicolson method given that h = k = 0.25.

How To Run Program Nicolson

1. Enter the program name Nicolson on the entry line and press the Enter key; i.e. Type Nicolson( ) and press the ENTER key.

2. The program then prompts you to enter the function U(x,0); In this illustration type x^2 – 1 and press the ENTER key.

3. Next the program prompts you to enter the number levels needed for the solution. For the purpose of this illustration, let us use three levels. Hence enter the number 3 and press the ENTER key.

4. The program then prompts for the step size in the direction of x, h. In this illustration h is given as 0.25 so. Enter 0.25 and press the ENTER key.

5. Finally the program prompts for the step size in the direction of t, k. Enter 0.25 and press the ENTER key.

The output for the solution at the three levels, as displayed on the screen, are presented in Figs 1, 2 and 3.

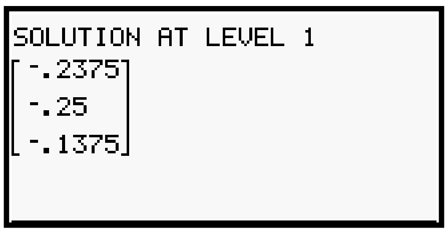


Fig. 1

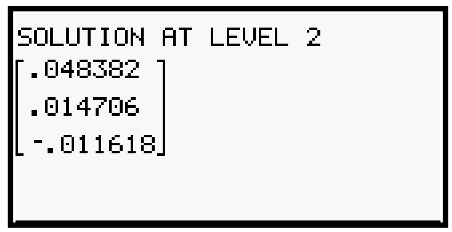


Fig. 2

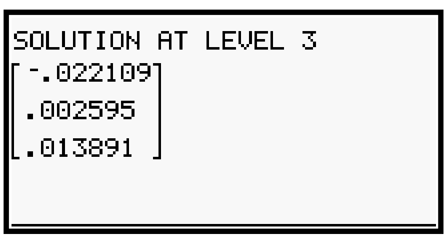


Fig. 3

Demonstration 2

The second activity demonstrates how the graphing calculator could be used to solve a system of non- – linear equations using the Shamanskii's method.

Outline of Method.

Step 1

Fix a positive integer $k \geq 1$ and choose a good initial guess $X^{(0)}$. At the i^{th} step, with $X^{(j)}$ known, in order to generate $X^{(j+1)}$ go to Step 2.

Step 2

For approximately small step size h_j of the same order as $\left\| f(x^{(i)}) \right\|_2$, let $\underline{e}_j$ denote the j^{th} column in the identity n x n matrix and compute the approximate Jacobian J_i, whose j^{th} column is given by

$$J_i \underline{e}_j = \frac{\underline{f}\left(\underline{x}^{(i)} + h_i \underline{e}_j\right) - \underline{f}\left(\underline{x}^{(i)}\right)}{h_j}, \quad 1 \le j \le n.$$

Step 3

Starting from $X^{(i)}$, perform k Newton iterations using the approximate Jacobian matrix, J_i (assumed non-singular). That is, compute the sequence $\left(y_i^{(j)}\right)_{j=1}^{k}$ by

$$y_i^{(0)} = x^{(i)}, \; y_i^{(j)} = y_i^{j-1} - J_i^{-1} \underline{f}\left(\underline{y}_i^{(j-1)}\right), \quad 1 \le \mathrm{j} \le \mathrm{k}$$

$$\text{and set } x^{(i+1)} = y_i^{(k)}$$

Step 4

If stopping criterion is not yet met, replace i by (i + 1) and go back to step 2

Owusu-Ansah (1999) described how the program code for the Shamanskii's Method could be coded into a TI-89, TI-92 and TI-92 Plus graphing calculators to solve a system of non-linear equations of any dimension. For details on how to do this, see Owusu-Ansah (1999).

Below are some examples of system of non-linear equations that can be solved using the program code called Shamaskii's written on the TI-89, TI-92 and TI-92 Plus graphing calculators.

$$y + \log x + 1 = 0$$

$$y - x^2 + 1 = 0$$

$$2u - 2\cosh v + 1 = 0$$

$$u - \cos v = 0$$

To be able to use the method of Shamaskii, an approximate solution or initial guess must be provided. However if the guess is not provided then we would have to resort to other methods like sketching if applicable, continuation method or others to find the approximate solution before using the Shamaskii's method to solve the problem. Owusu-Ansah (1999) also described how to employ the continuation method to find the initial guess. Usually, a program code for the continuation method, called 'Cont_mtd', is first coded into the graphing calculator.

How To Run Program Cont_mtd

1. Enter the program name Cont_mtd ( ) on the entry line and press the ENTER key i.e. Type Cont_mtd ( ) ENTER
2. You are then prompted to enter the number equations. In our illustration, the number of equations is four so Type 4 and press the ENTER key
3. NOTE: If the RHS of your equation is not a zero, rearrange it to have a zero as the RHS and enter the LHS of each resulting equation replacing x by x1, y by x2, u by x3 and v by x4 etc. followed by the pressing of the ENTER key. For example for equation 1 Type x2 + ln(x1) + 1 and press the ENTER key. Equations 2, 3 and 2 are entered in a similar manner
4. You are then prompted to enter the equation of known solution i, i=1,2,3,4. It must however be noted that these equations are chosen arbitrary. In our illustration, x1 – 1 = 0, x2 – 1 = 0, x3 – 1 = 0, x4 – 1 = 0 with solutions (1,1,1,1) are chosen to represent equations 1, 2, 3 and 4 respectively.
5. You are then prompted to input the step size to, 0 < to ≤ 1. For this demo, we chose $t_o = 0.1$ so enter 0.1 and press the ENTER key.
6. Finally enter 10^-5 or press the keys EE - 5 as tolerance and press the ENTER key.

Figs. 4 and 5 represent the screen displays of the Jacobian matrix at the final iteration, with the initial guess displayed in Fig. 6.

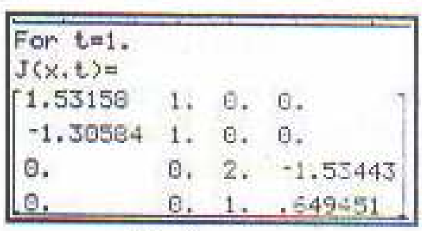


Fig. 4

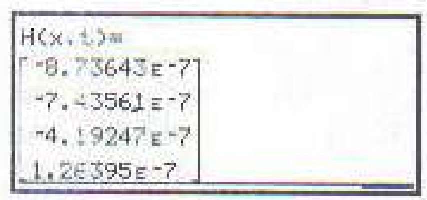


Fig. 5

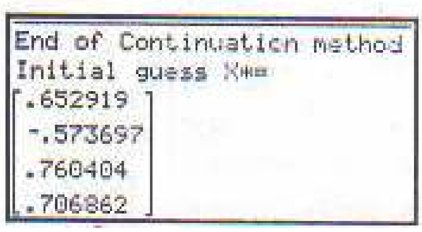


Fig. 6

It follows then that the initial solution for our problem, is approximately $(.65, -.57, .76, .71)^T$

Having obtained the initial guess we can now go ahead to run the program Shamaski which we coded earlier on(if you have not yet coded, do so now before you continue),to find the solution to the given system of equations.

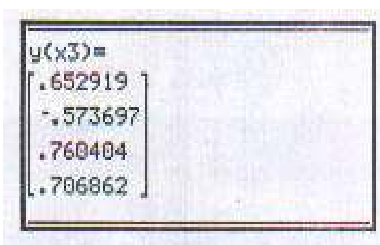
How To Run Program Shamaski

1. Enter the program name Shamaski( ) on the entry line and press the ENTER key i.e. Type Shamaski( ) ENTER.
2. You are then prompted to enter the number equations. In our illustration, the number of equations is four so Type 4 and press the ENTER key
3. You are then prompted to enter equation i, i=1,2,3,4.

   NOTE: If the RHS of your equation is not a zero, rearrange it to have a zero as the RHS and enter the LHS of each resulting equation replacing x by x1, y by x2, u by x3 and v by x4 etc. followed by the pressing of the ENTER key. For example, for equation 1,

   Type x2 + ln(x1) + 1 and press the ENTER key Equations 2, 3 and 2 are entered in a similar manner.
4. Next the program prompts the value of k≥1. In our illustration let us use k=3; i.e. Enter the number 3 and press the ENTER key.
5. You are then prompted to enter the initial guess. NOTE: The initial guess is a vector and as such must be entered as an n x 1 matrix; i.e. Type [65; -.57 ; .75 ; 71] and press the ENTER key
6. Finally enter 10^-5 or press the keys **EE - 5** as tolerance and press the ENTER key

At the last stage of the iteration (3^{rd} iterate) the screen displays for the solution are as shown in Fig. 7, 8, 9 and 10



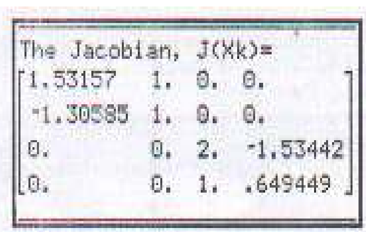
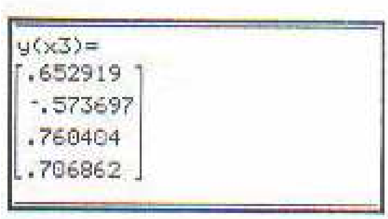


Fig. 7 Functional value & stepsize

Fig. 8 Jacobian matrix



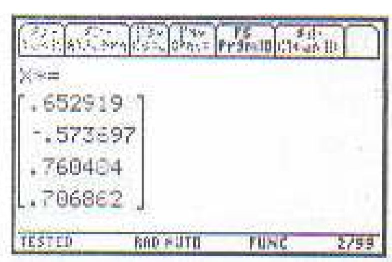


Fig. 9 3^{rd} Newton iterate

Fig. 10 Final Solution

Demonstration 3

The third activity demonstrates how the graphing calculator is used to find all the roots of a polynomial with complex roots using the method of Durand and Kerner.

Outline of Method

Let α_1, α_2, , α_n denote all the zeros of a polynomial

$$Pn(z) = z^n + a_{n-1}z^{n-1} + a_{n-2}z^{n-2} + \cdots + a_0$$

Then using Vieta's formulae given below :

$$f_1(\alpha) = \sum_{i=1}^{n} \alpha_i + a_{n-1} = 0$$

$$f_2(\alpha) = \sum_{i<j} \alpha_i \alpha_j - a_{n-2} = 0$$

– – – – – – – – – – – – – –

– – – – – – – – – – – – – –

$$f_n(\alpha) = \prod_{i=1}^{n} \alpha_j + (-1)^{n+1} a_0 = 0$$

where $\alpha = (\alpha_1, \alpha_2, \cdots, \alpha_n)^T$

Letting $f(\alpha) = (f_1(\alpha), f_2(\alpha), \cdots f_n(\alpha))^T$ and letting $J(\alpha)$ denote the Jacobian matrix of f with respect to α, we apply the Newton's method to the system of equations above to obtain the iteration

$$\alpha^{(k+1)} = \alpha^{(k)} + P^{(k)}$$

where $P^{(k)} = -J(\alpha^{(k)})^{-1} f(\alpha^{(k)})$ $x^{(0)}$ being arbitrary

In this instance

$$P^{(k)} = \frac{-Pn(\alpha_i^k)}{\prod_{i \neq j}^{n} (\alpha_i^{(k)} - \alpha_j^{(k)})}, \qquad i = 1, 2, \cdots n$$

(see Trevison (1997)).

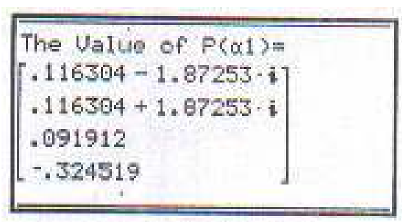
Owusu-Ansah (1999) also described the Program code for the Durand and Kerner method, which could be coded into a TI-89, TI-92 and TI-92 Plus graphing calculators, to find the zeros of a polynomial of any of any order. When written on the TI-89, TI-92 and TI-92 Plus graphing calculators, the Durakena program code ca be used to find all the roots of the polynomial $16x^4 - 48x^3 - 176x^2 + 158x + 245 = 0$, given that the initial guess is (3 + i, 3 – i, -1, -2)^T.

How To Run Program Durakena

Step 1

1. Enter the program on the entry line and press the Enter key; i.e. Type durakena( ) and press the ENTER key.
2. The program then prompts you to enter the coefficients of the polynomial as a list. In our illustration type the following: {16, -48, -17, 158, 245 } and press the ENTER key.
3. Finally enter 10^-6 press the keys **EE - 5**, as the tolerance and press the **ENTER** key.

Fig. 11 and 12 shows the screen displays for the 1st iteration of program durakena



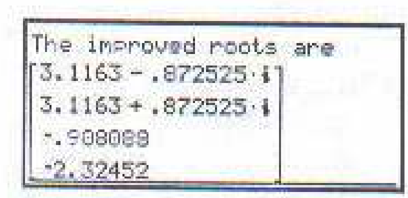


Fig.11 $P^{(k)}$ with k = 1 Fig.12 $\alpha^{(j+1)}$ with j = 0

The final solution obtained is

$$X^* = \begin{bmatrix} 3.3369 - 1.06553i \\ 3.3369 + 1.06553i \\ -.378728 \\ -3.29507 \end{bmatrix}$$

Fig. 13 Final solution, X*

Demonstration 4

In our fourth demonstration, we use the graphing calculator to establish the actual effect of different integration methods by using the epidemic model that follows.

$N^{'}(t) = 0.002N(t)\{1000 - N(t)\}; \quad \mathrm{N}(\mathrm{t}) = 10$, whose true solution is

$$N(t) = \frac{1000}{1 + 99e^{-2t}}$$

where N(t) is the number of people affected by the epidemic at any time, t.

Table. 1 shows the comparison of the computational times of the TI-92 Plus and a 486 computer.

Table. 1 Comparison of the computational times of the TI-92 Plus and 486 computer.

		COMPUTATIONAL TIME	
METHOD	STEP SIZE	486 COMPUTER	TI – 92 PLUS
2^{ND} Order Runge Kutta	0.1	12sec	12sec
Explicit Euler Method	0.01	70sec	67sec
Explicit Euler Method	0.1	10sec	6.2sec
Explicit Euler Method	2	1 sec	0.78 sec

Comments

Some of the shortcomings of graphing calculators are:

1. The small nature of the user available RAM which makes it unsuitable for solving problems demanding big data sets.
2. The speed of the processor of graphing calculators is also worth mentioning. As at now, the fastest graphing calculator uses a processor with 10 MHz speed. In fact this makes their usage in solving real life problems where the data are normally large, painfully slow. However if problems could be reduced into sub-problems, this problem fairly reduces to the barest minimum.

On the positive side, if graphing calculators are well integrated into various courses. Lecturers would have ample time to explain concepts and methods instead of spending so much time explaining how computations are done manually. The students on the hand may not have to worry so much about

computational errors which may result from some awkward computations but focus on how to link concepts and the methods to achieve the optimum.

Conclusion

With the necessary peripherals like overhead projectors, cables for communication between calculators and computers, printers etc. graphing calculators could easily be integrated into the course structure of mathematics to facilitate its teaching and learning.

Even where computers are not available or sufficient, graphing calculators could serve as a very good substitute if little trouble is taken to write some program codes for the corresponding problems.

Recommendations

1. Rather than discouraging the use of graphing calculators, students and lecturers alike need to be encouraged to use graphing calculators.
2. There should be a conscious effort by Mathematics departments to promote the use of graphing calculators by way of setting up a laboratory of graphing calculators where further research could be conducted on the capabilities of graphing calculators.
3. Regular workshops should be organised to enable instructors, students, lecturers etc to update their knowledge and also share ideas with other people in the calculator industry and also the state of the art knowledge of graphing calculators.

Reference

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Trevison (1977) *A zero finding algorithm for complex polynomial* MSc. Thesis, Department of Computer Science University of Toronto.

Drug Abuse among the Youth in Ghana

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Abstract

Drug abuse is becoming a serious problem. The course of the alarming rate of the abuse especially among the youth can be traced to the high unemployment among the youth, the frustration of highly qualified students not having access for further education and the general economic situation in the country. Marijuana has been identified as the major drug of abuse among the youth in Ghana. The age of incidence of abuse of marijuana is relatively low, 10 -12 years and experimentation has been found to be the main reason for the start of the abuse.

Introduction

The use of marijuana, locally known as "*wee*" among students in secondary schools, unemployed youth especially in the urban areas, is commonly known and frowned on or by the community.

The increase in the use and abuse of marijuana among the youth in Ghana can be associated with the rapid social changes that generally result from rural-urban migration. Illicit trafficking of marijuana (wee) has also been on the ascendancy and, unfortunately, the illicit trafficking of other hard drugs like heroin and cocaine and psychotropic substances has also been noticeable. The serious economic recession that Ghana has been experiencing cannot escape blame as one of the factors for the rise in illicit trafficking of hard drugs.

Following the introduction of the Education Reform Program in 1986 many qualified students have been rendered frustrated due to their inability to gain admission to the universities and other tertiary educational institutions. They have thus become vulnerable to and easy prey for the drug barons to recruit as couriers for the hard drugs to Europe and the USA. The recent spate of armed robberies and increase in rape cases around the country may not be totally unassociated with the alleged increase in the abuse of narcotic drugs. It may also not be far-fetched to link the highly visible wealth in the cities and the ostentatious living styles of some businessmen and women with narco-dollars and money laundering.

Drug abuse is a highly pervasive problem. Its impact on individual lives, on families and communities and on the socio-economic well-being of the nation, is horrendous. Every effort must therefore be taken to contain its consequences.

Extent of Drug Abuse among Students in Ghana

Because of the destructive effects of drug abuse on the users, parents, teachers, friends, religious and community leaders and law enforcement agencies, serious concern about the drug abuse problem is generally expressed by the Government. Indicators that marijuana or 'wee' is seriously abused in the country can be found in the boarding and day secondary schools, lorry parks, recreational grounds, on the beaches and some areas in the cities and rural areas and in the prisons. It is known that the cannabis plant is illicitly grown in large quantities in the rural and sub-urban areas in the country.

Ghana has been identified as a major transit point for cocaine and heroin from South America and Asia respectively. Many Ghanaians are known to be in prison in the USA, Europe and Asia for drug trafficking offences. The International Criminal Police Review, March 1996, No 396 issue, reported the arrests of 75, 138 and 115 Ghanaians in Europe in 1982, 1983 and 1984 respectively for marijuana trafficking.(Barr, 1986). Statistics from the psychiatric hospitals here in Ghana indicate that from 1993 to 1998 marijuana was the pre-dominant drug of abuse among the patients as shown in Table 1. Drug-related arrests made by the police in 1997 and 1998 also showed that marijuana was the main drug of abuse as shown in Table 2.

Table 1 Distribution of Predominant Drugs among the Patients

	1993	1994	1995	1996	1997	1998
Cannabis (Wee)	65.6	56.2	49.9	43.6	69.6	70.7
Alcohol	15.8	17.5	14.6	16.5	15.1	17.5
Cocaine	2.3	2.3	0.04	0.05	0.009	0.04
Heroine	3.1	2.2	2.5	1.5	0.0009	1.3
Multiple	11.7	11.6	15.6	11.4	14.2	9.9
Pethidine	0.01	0.04	0.02	0.04		0.009
Unspecified	1.3	10	16.57	7.7		0.02
	99.81	99.84	99.23	80.79	98.9099	99.469

Table 2 Drugs Related Arrests for 1997 and 1998

	Cocaine		Heroin		Cannabis Sativa		Unspecified	Total
	Male	Female	Male	Female	Male	Female		
1997	16	1	30	5	315	13	9	389
1998	18	0	24	1	170	2	0	215

(Compiled by The Ghana Narcotics Control Board)

A study by Senah et al (1998) found marijuana to be number one on the list of narcotic drugs abused in Ghana while amphetamines were the most commonly abused psychotropic drug among secondary school students.

The monograph titled "The Drug Nexus in Africa" (1998) which was one of the series of monographs prepared by the United Nations Office for Drug Control and Crime prevention (UNODCCP) rated Ghana as the second largest producer of marijuana in West Africa. Cocaine and heroin were also reported in the monograph to be available in Ghana while the cheaper 'crack' cocaine was reported to be consumed locally, having been processed locally from cocaine base using simple "kitchen" technologies.

The most recent study on drug abuse among Ghanaian students by Brown-Acquaye et al (2000) established that:

1. Most students are aware of the risks involved in abusing hard drugs and alcohol.
2. The percentage number of students abusing marijuana(wee) is low compared to the general public impression.
3. The age at which students start smoking marijuana(wee) is very low, 10-12 years, the period of adolescence when the youth begin with struggle for independence and self-identity.
4. Experimentation is the main reason for the students' incident use of marijuana.
5. Social gatherings were the venues for the smoking of the drugs. The bushes and hedges around the schools and toilets are also used to smoke the marijuana.
6. Most students are not familiar with cocaine, heroin and crack cocaine and even has wish.
7. Amphetamines are the psychotropic substances mostly abused by students because of their stimulating effects.
8. Tranquilizers are not very popular with students.
9. Trafficking of marijuana is very rampant and on the increase.
10. Students who abuse marijuana are aware of the risks and harmful effects of the drug.
11. Students are not frequently used as couriers in the trafficking of drugs to Europe and the USA. Unemployed youth are rather mostly used.

Discussion

In the past the supply of drugs to the international market was considered to be engaged in by only the developing countries while the industralised countries were considered to be the consumers of those smuggled drugs. The trend has now changed and the use and abuse of hard drugs have now spread at an alarming rate and have reached all corners of the world.

The Pan American Health Organisation (PAHO) from its studies has underlined "the need to stop polarizing the problem as a matter of 'producer' and 'consumer' countries since abuse is increasing steadily among the population" (PAHO, 1989).

The exact nature of drug problems varies from one country to another and therefore calls for different types of possible solutions.

According to Lutchman (1989) each country should be able to locate itself on a continuum of drug-related experiences. He categorised countries as those that have:

1. Little or no drug involvement and no immediate threat of involvement.
2. Some drug involvement but little or no acknowledgement of current or potential problems.
3. Some drug involvement and considerable concern about emerging and potential problems.
4. Considerable involvement and considerable concern about the problem.

On the above scale, Ghana may be placed in the third category. Having thus been positioned, it then becomes imperative to build an organizational capacity to address the problem and to realise that the problem of drug abuse and trafficking cannot be solved overnight. To address the problem the whole community of Ghana must be involved.

From the study by Brown-Acquaye et al (2000), it was established that marijuana is the drug mostly abused by students and that the incident age is between 10 to 12 years. This is a frightening situation for the future development of the youth, if they are to become drug addicts.

The historic approach generally adopted for human needs, whereby people are allowed to develop severe problems before enormous resources are expanded to address the issues, must not be adopted for drug issues. The factors that account for the situation in which the youth, as young as ten (10) years of age, start smoking marijuana must be identified and ruthlessly and vigorously eliminated. The traditional intervention strategy of reducing the problems associated with drug abuse must now give way to prevention strategy – not intervention. This is the time to champion "zero" tolerance for drug use. The goal of prevention should be to discourage the initiation of drug use. The incidence rate of drug consumption by occasional or experimental users must be reduced to *zero.*

To achieve this, the whole community must be involved and cultural and moral values must be inculcated into the youth. The encroachment of foreign cultures into the Ghanaian lifestyles is a major cause of the drug

abuse problem and this must be addressed on community basis through the District Assemblies.

With comprehensive prevention strategies aimed at bringing down the incidence rate to *zero,* it would be possible to have, in the very near future, drug-free communities in Ghana.

Another aspect of the drug menace which needs serious attention is illicit trafficking of drugs. To combat the drug abuse and illicit trafficking, it should be realized that, after the cold war era, the drug business has now a global reach. Hence it is only through international cooperation that some ray of hope may appear at the end of the tunnel.

The report of the Centre for Strategic and International Studies (CSIS) project on the Global Drug Trade in the Post-Cold War Era (1988) stated inter alia "The identification of drug trafficking as a criminal activity seems to foster the simplistic notion that it can be cured with sufficient doses of law enforcement. But to confront the problem directly, it is more helpful to view drug trafficking as an international business or more accurately, as a commodity trade conducted by transnational consortiums. The magnitude and complexity of these business operations mandate that the drug industry pattern itself after the modern multi-national cooperation".

The consequences of drug abuse and illicit drug trafficking are more horrendous and disastrous for any nation than the consequences of the now much heralded HIV/AIDS epidemic. The euphoria surrounding the HIV/AIDS issue portray lack of awareness of the real effects of drug abuse and illicit trafficking on any nation. The social and economic effects of drug abuse and illicit drug trafficking are really devastating for <u>any</u> nation, great or small.

"The war on drugs cannot be won alone by soldiers in the jungles of South America or police officers in the alleys of our cities, or lab technicians in the health departments of our business. Skirmishes can be fought there, but the war must be won in the conscience, the attitude, the character of Americans as a people. So long as we tolerate drugs, think they are sophisticated or midly risqué, we will never rid ourselves of this national albatross" (Herrington, H.L. 1996).

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